3 FREE DIGITAL BOOKS

TEACH YOURSELF ASTROPHOTOGRAPHY • WORLD OF TOMORROW • MENSA HIGH IQ TEST

WORTH £30

All About Space™

HUMANS ON TITAN

Why Saturn's moon is tipped to be our next home

SECRETS OF STARDUST

...and how it affects Earth's climate

THE BIG BANG

Is the theory of the cosmos wrong?

PLANET NINE CONTROVERSY

THE SOLAR SYSTEM'S BLACK HOLE

Is our cosmic backyard home to the universe's most ancient phenomena?

+

FUTURE MISSIONS
YOUR NIGHT SKY GUIDE
LATEST NEWS

BEGINNERS GUIDE TO ASTRONOMY

- ✓ FREE DIGITAL POSTER
- ✓ WHAT TO SEE
- ✓ BEST DARK-SKY PARKS

NEW RESEARCH

WHY LIFE CAME FROM COMETS

FUTURE
ISSUE 108

CELESTRON

NEXSTAR SE COMPUTERISED TELESCOPE & ACCESSORIES

Enhance your stargazing experience with a selection of our best-selling accessories. Make the most of each night under the stars.

VISUAL

Eyepieces, Barlows, and Eyepiece Kits

Enhance your view through any scope

NAVIGATION

SkyPortal WiFi Module

Control your telescope via smartphone

IMAGING

NexYZ 3-Axis Universal Smartphone Adapter

Capture the universe with our bestselling smartphone adapter

POWER

PowerTank Lithium

Up to 10 hours of portable power

CASES

Telescope Carrying Case

Keep your telescope safe and secure

Find out more at **celestron.com**

Or contact Celestron in the UK on 0118 4671 200

GET FREE ALL ABOUT SPACE BONUS CONTENT
SIGN UP ONLINE AT SPACEANSWERS.COM/NEWSLETTER

Space dust reveals myriad secrets about Earth and the universe

Welcome

If you've ever wanted to get into astronomy – also known as stargazing, as some of our readers like to call it – then this is the issue for you.

From selecting the ideal observing site to the best targets to spot whether you're using binoculars, a telescope or the unaided eye, we've got everything you need to ensure you're armed with the right advice when it comes to exploring the heavens. Turn to page 62 for your complete guide.

For those who just can't get enough of the longer, darker hours, our observing section continues with our usual full palette of naked-eye and deep-sky objects, Moon tour, planet guide, Northern Hemisphere map and astronomical calendar through September to October 2020.

If the weather in your part of the world has taken a turn for the worse over the past few weeks after the glorious run of warmer, clearer nights, then we've still got plenty to keep you entertained this issue: my personal highlights are our special reports on whether life came from comets over on page 44 and what cosmic dust can teach us about our very own planet on page 34.

Our cover feature is sure to inspire too, as we return to Planet Nine. Have we got our wires crossed in determining its true identity? Some experts think we have, suggesting that a black hole could be lurking at the Solar System's edge, masquerading as a distant world...

Gemma Lavender
Editor-in-Chief

Our contributors include...

Colin Stuart
Space science writer
Was life as we know it delivered to Earth by comets? According to Colin's recent findings, it's looking very likely. Turn to page 44 for the full details.

Sean Solomon
Planetary scientist
What have we learned about Mercury? Sean reveals details from the defunct MESSENGER mission alongside our panel of space and science experts.

Pavlo Tanasyuk
CEO of Spacebit
Pavlo is aiming to launch the UK to the Moon with his space start-up company Spacebit. Discover more about his plans to explore lunar lava tubes on page 31.

Lee Cavendish
Staff Writer
There's a missing link to the universe, and without it the cosmos makes no sense. Lee meets the astrophysicists trying to solve the puzzle.

ALL ABOUT SPACE ISSUE 109 ON SALE 8 OCTOBER!
Available from supermarkets, newsagents and online at myfavouritemagazines.co.uk

© Getty

Keep up to date

Online
www.spaceanswers.com

Facebook
/AllAboutSpaceMagazine

Twitter
@spaceanswers

CONTENTS

www.spaceanswers.com

TWEET US
@spaceanswers

POST ON FACEBOOK
/AllAboutSpaceMagazine

SEND US AN EMAIL
space@spaceanswers.com

LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

06 Saturn puts on a show, a Milky Way lookalike is found, the end of the universe is calculated and the mystery of Betelgeuse's dimming is solved

FEATURES

14 **The Solar System's black hole**
As the hunt for Planet Nine steps up, something more exotic could fit the bill

22 **Future tech**
Fishing on other worlds

24 **Escape to Titan**
When the Sun scorches Earth, a tiny moon in orbit around Saturn is our next home

30 **Interview**
2021: the year Britain launches for the Moon

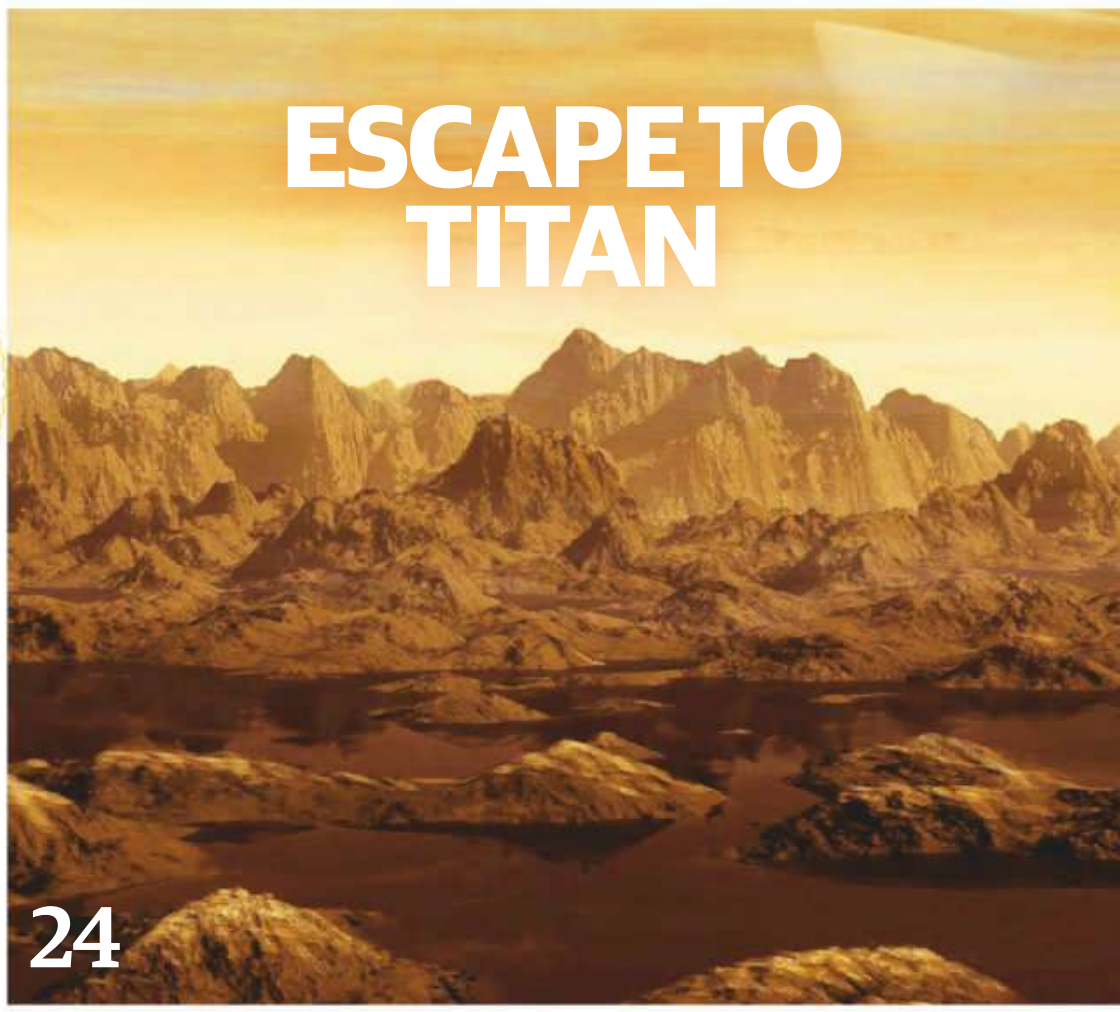
34 **Cosmic dust**
What does it reveal about the universe?

40 **Focus on**
Do Earth-like planets orbit our galaxy's black hole?

44 **Did life come from comets?**
They race in and out of our Solar System, and according to evidence, they could have brought life with them

50 **Our universe's missing link**
The model of the cosmos needs revision, but not without astronomers first assembling the pieces of a new cosmological puzzle

58 **Ask Space**
Your questions answered by our space experts



FREE *THE SPACE RACE* BOOK BY SARAH CRUDDAS

Worth £16.99

TURN TO **PAGE 42** FOR DETAILS

3 FREE eBOOKS WORTH £30!

57 Download **Teach Yourself Astrophotography, World of Tomorrow** and **Mensa High IQ Test** today

OUR UNIVERSE'S MISSING LINK

50

34

COSMIC DUST

DID LIFE COME FROM COMETS?

44

STARGAZER

Your complete guide to the night sky

62 **Get into stargazing**
Start off on the right foot with our full guide

68 **What's in the sky?**
As we pass the midpoint of darkening skies, see what autumn has to offer

72 **Month's planets**
Dusk to dawn belongs to the ice giants this month

74 **Moon tour**
How to find the most dramatic cliff on the face of the Moon

75 **Naked eye and binocular targets**
Find spiral galaxies that lie many light years away

76 **Deep sky challenge**
A ghostly nebula and a rose-shaped star cluster await you

78 **The Northern Hemisphere**
The skies offer myriad targets for astronomers this month

80 **Telescope review**
Is the Celestron NexStar 127 SLT the right telescope for you?

WIN!

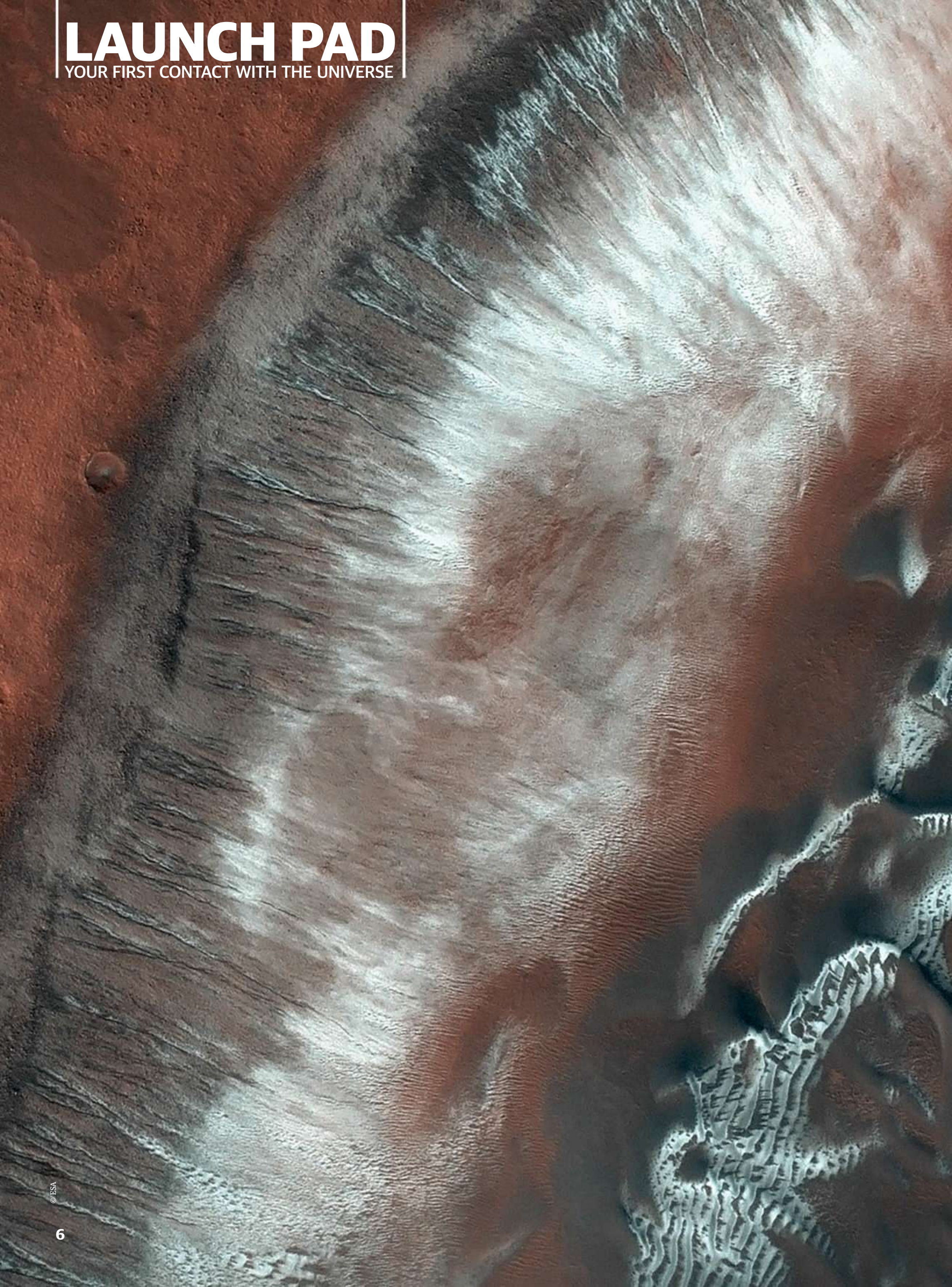
OMEGON MINITRACK LX3 MOUNT

WORTH £169!

13

LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE



© ESA

Mars' double Green Crater

The European Space Agency (ESA) and Russia's Roscosmos jointly operate the ExoMars Trace Gas Orbiter, which is currently circling the Red Planet and snapping images of its terrain with high clarity and resolution. The subject of this picture, taken on 27 April 2020, is a crater inside a larger impact, known as Green Crater. Both of these craters are located in Argyre quadrangle region of the Mars' southern hemisphere. The ExoMars team are currently studying this image to investigate how seasonal ice – shown here as bright, white patches – relates to the presence of gullies on the surface.

Saturn gets a check-up

On 4 July 2020 Saturn had its regular check-up with the NASA/ESA Hubble Space Telescope. Images like these are performed to see if the ringed planet is showing any signs of change on its surface and impressive ring system. At the moment this image was taken, Saturn was around 1.4 billion kilometres (839 million miles) away from Earth, yet Hubble was able to capture the gap between the rings – the Cassini Division – as well as the bands crossing the planet's atmosphere with impressive clarity.

Copernicus' colourful picture of Earth

Space-based cameras are able to capture the beauty of Mother Nature from a unique viewpoint. The ESA's fleet of satellites watching over Earth, as part of the Copernicus programme, captured this visually stunning shot of the Flinders Ranges, a mountainous location in southern Australia, on 31 December 2019. However, this image – snapped by Copernicus Sentinel-2 – was only recently released on 31 July 2020. Depicted in false colour, the shot showcases a fabulous array of vibrancy and curves, emphasising Earth's geological features.

© NASA/ESA

© ESA

© ESA

Beam me up, Scotty

While Antarctica is stuck in a perpetual state of darkness during its winter, astronomers at the Concordia Research Station are busy conducting observations that provide valuable scientific insights. Without the interfering presence of daylight, the Light Detection and Ranging instrument's (LIDAR) laser is able to pierce the sky in order to find out more about our planet's atmosphere. Scattered light is recorded by sensors and reveals more about atmospheric density, temperature, wind speed, cloud formation and aerosol particles.

Studying this galaxy could tell us more about our own

Milky Way lookalike found 12 billion light years away

Words by Elizabeth Howell

Peering into the early universe, astronomers uncovered a surprise: a young galaxy that looks a lot like the Milky Way. The newfound galaxy is called SPT0418-47, and given its great distance from Earth, astronomers see the galaxy as it was when the universe was just 1.4 billion years old – roughly 12 billion years before today.

The discovery held a big surprise for the researchers: stars were forming quickly, as expected, since there was abundant gas available when the universe was young. But despite the chaos, SPT0418-47 has a well-defined, rotating disc and galactic 'bulge' at the centre. That's a similar structure to the Milky Way's today.

Analogies between SPT0418-47 and the Milky Way are not perfect, however. The Milky Way sports a distinctive barred-spiral shape, formed by large 'arms' of stars and gas. But SPT0418-47 lacks such arms. Moreover, scientists expect it will evolve into another galaxy type entirely, an elliptical galaxy.

Yet the newfound galaxy does give insight into the evolution of these massive star-filled structures over the eons. Based on this new find, it appears there may have been less dramatic galaxy changes than previously imagined. "The structures that we observe in nearby spiral galaxies and in our Milky Way were already in place 12 billion years ago," said Francesca Rizzo, a PhD student from Germany's Max Planck Institute for Astrophysics.

It was the powerful Atacama Large Millimeter/submillimeter Array (ALMA) that allowed astronomers to spy on SPT0418-47. ALMA consists of 66 antennae scattered across the Chilean desert, working together to create one large telescopic lens. The newfound galaxy was too faint to be observed directly, so ALMA used a technique called gravitational lensing to overcome the problem, magnifying SPT0418-47's light using the gravity of a nearby galaxy.

Gravitational lensing can sometimes produce some distortion, but in this case the alignment between the two galaxies was almost exact. This makes SPT0418-47 appear as a nearly-perfect ring in the raw images. Rizzo and her team found the true shape and gas motion of the galaxy using a computer model.

Future telescopes, such as the European Southern Observatory's Extremely Large Telescope, will peer further into the early universe to better figure out how common SPT0418-47's shape was among the galactic

"THE NEWFOUND GALAXY DOES GIVE INSIGHT INTO THE EVOLUTION OF THESE MASSIVE STAR-FILLED STRUCTURES OVER THE EONS"

© ALMA

Scientist calculates the 'sad, lonely' end of the universe

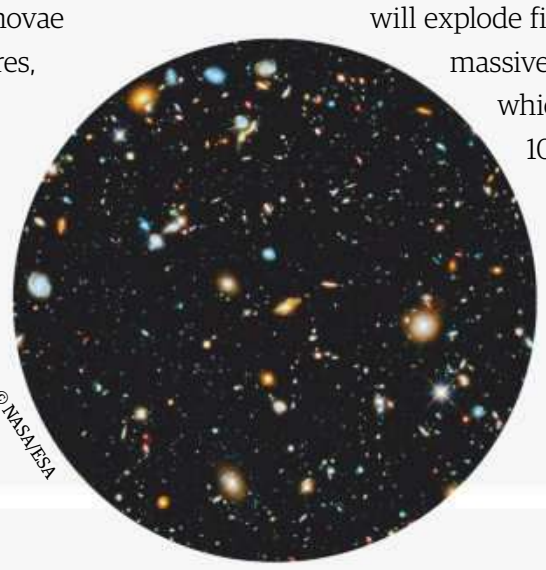
Words by Chelsea Gohd

Stars will continue to explode long after the universe is cold and 'dead', one scientist determined after diving down the rabbit hole to find the last supernova that will ever happen. The universe's end is "known as 'heat death,' where the universe will be mostly black holes and burned-out stars," said Matt Caplan, an assistant professor of physics at Illinois State University. "I became a physicist for one reason. I wanted to think about the big questions – why is the universe here, and how will it end?"

Caplan looked to the future of stellar explosions. Massive stars explode in supernovae when iron builds up in their cores, accumulating and triggering the star's collapse. But smaller stars such as white dwarfs – ultradense stellar corpses that form when Sun-like stars exhaust all of their nuclear fuel – don't have the gravity and density to produce this iron. However, Caplan discovered that over time white dwarfs might become denser and become 'black dwarf' stars that can actually produce iron.

Caplan calculated that the first of these 'black dwarf supernovae' will explode in about $10^{11,000}$ years – an almost inconceivably large number. "In years it's like saying the word 'trillion' almost a hundred times. If you wrote it out, it would take up most of a page. It's mind-bogglingly far in the future," he said.

He found that the most massive black dwarfs will explode first, followed by less and less massive stars until there are none left, which he expects will be in about $10^{32,000}$ years. "It's hard to imagine anything coming after that," he said. "Black dwarf supernovae might be the last interesting thing to happen in the universe. They may be the last supernova ever."



© NASA/ESA

Betelgeuse's bizarre dimming caused by eruption

Words by Mike Wall

In the autumn of 2019, red giant Betelgeuse began dimming significantly, losing about two-thirds of its brightness by February. This dramatic dip spurred speculation that the star's demise may have been imminent – perhaps just weeks away, from our perspective, anyway. Betelgeuse lies about 500 light years from Earth, so everything we're seeing with the star today happened centuries ago.

But the dramatic sky show didn't happen: Betelgeuse powered through the dimming episode and returned to its normal brightness by May of this year. The recovery sparked a new round of speculation, this time about the dimming's cause. Some scientists attributed the doldrums to a light-blocking dust cloud, whereas others said big starspots on Betelgeuse's surface were likely to blame. The dust hypothesis adds a twist – Betelgeuse itself apparently coughed up the cloud.

Researchers studied the star in 2019 and 2020 using the iconic Hubble Space Telescope. Hubble's observations from September through November 2019 revealed huge amounts of material moving from Betelgeuse's surface to its outer atmosphere at tremendous speeds – about 320,000 kilometres (200,000 miles) per hour. During this three-month-long outburst, Betelgeuse lost about twice as much material to space from its southern hemisphere as it normally does. Betelgeuse's background shedding rate is significant – about 30 million times that of our Sun's.

© NASA/ESA

HOW IT WORKS

subscription offer

FROM £2.38 PER ISSUE!

ENJOY INSTANT READING

Our digital editions come with the same features included in the print edition!

This offer is **only** available via our online shop

www.myfavouritemagazines.co.uk /hiwd/DIGCSP20

© SpaceX

SpaceX's next astronaut launch for NASA pushed to October

Words by Chelsea Gohd

SpaceX's next astronaut mission faces another delay. The target launch date for SpaceX's Crew-1 mission, its first fully operational crewed mission to space, has been pushed back to no earlier than 23 October. The mission, which is set to launch SpaceX's Crew Dragon spacecraft atop a Falcon 9 rocket from NASA's Kennedy Space Center, won't lift off until at least late October to accommodate spacecraft traffic for the upcoming Soyuz crew rotation and to best meet the needs of the International Space Station.

Crew-1 will carry four astronauts to and from the space station – NASA astronauts commander Michael Hopkins, pilot Victor Glover and mission specialist Shannon Walker and Japan Aerospace Exploration Agency (JAXA) astronaut mission specialist Soichi Noguchi. With this new timeline, Crew-1 will launch after NASA astronaut Kate Rubins and cosmonauts Sergey Ryzhikov and Sergey Kud-Sverchkov arrive at the space station aboard the Russian Soyuz MS-17 craft. Crew-1's liftoff will also follow the departure of NASA astronaut Chris Cassidy and cosmonauts Anatoli Ivanishin and Ivan Vagner from the station.

Crew-1 will follow the success of SpaceX's historic Demo-2 mission. Demo-2, the first orbital crewed flight test of a commercially owned and operated human spacecraft, carried NASA astronauts Bob Behnken and Doug Hurley to and from the space station aboard a Crew Dragon capsule. Commercial spaceflight milestones like the successful completion of Demo-2, and soon Crew-1, will enable NASA to regularly fly astronauts to the space station, ending sole reliance on Russia for space station access.

Above: Commercial spaceflight is the next big step in human space exploration

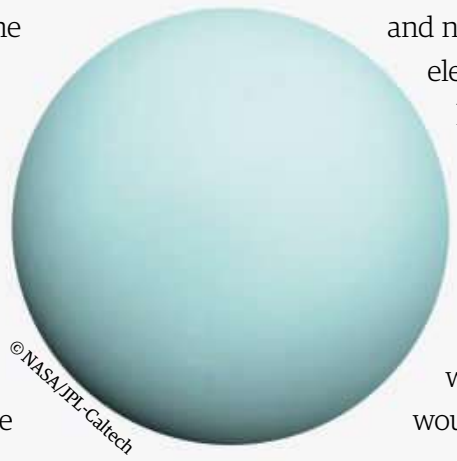
Scientists probe weird alien water inside Uranus and Neptune

Words by Chelsea Gohd

Scientists have devised a theoretical computer model and used it to peer inside the ice giants Uranus and Neptune. With this tool a team studied the thermal and electrical conductivity of the unusual water inside these planets. In simulating these physical processes on a tiny atomic scale, the researchers hope that this new model will reveal information about the icy bodies' internal structure, magnetic fields, how they evolved and exactly how old they are.

In studying Uranus and Neptune with this model, the researchers, who stem from the International School for Advanced Studies (SISSA) in Trieste, Italy, and the University of California at Los Angeles, estimated that the two planets are likely primarily composed of water in some form, and Uranus might even have a frozen core. "Hydrogen and oxygen are the most common elements in the universe, together with helium. It is easy to deduce that water is one of the major constituents of many celestial bodies," the researchers said.

"In such exotic physical conditions, we cannot think of ice as we are used to," SISSA professors Federico Grasselli and Stefano Baroni said. "Even water is actually different, denser, with several molecules dissociated into positive and negative ions, thus carrying an electrical charge. Superionic water lies somewhere between the liquid and solid phases." The researchers hypothesise that Uranus might actually have a frozen core. This would explain why the planet isn't very luminous, as a frozen core would mean that very little heat would move towards the surface.



©NASA/JPL-Caltech

Left: These results further our understanding of exactly how the two bodies are composed and how they came to be

IN COOPERATION WIT SPACE.com

NASA powers up Mars helicopter for the first time

Words by Samantha Mathewson

NASA's Mars helicopter, named Ingenuity, successfully powered up for the first time in space last week. Ingenuity is the first helicopter designed to fly on another planet. It is currently travelling to the Red Planet aboard NASA's Mars 2020 Perseverance rover, which launched on 30 July.

On 7 August the helicopter's six lithium-ion batteries were powered up and charged for the first time in space. The 1.8-kilogram (four-pound) Ingenuity, which is currently stowed beneath Perseverance's belly, receives its charge from the rover's power supply.

"This was a big milestone, as it was our first opportunity to turn on Ingenuity and give its electronics a 'test drive' since we launched on 30 July," said Tim Canham, the operations lead for Mars Helicopter at NASA's Jet Propulsion Laboratory (JPL) in California. "Since everything went by the book, we'll perform the same activity about every two weeks to maintain an acceptable state of charge."

© NASA/JPL-Caltech

Right: The Mars helicopter is the first of its kind

WIN

OMEGON MINITRACK LX3 MOUNT

Take your astrophotography to the next level with this mechanical mini-mount

The Omegon MiniTrack LX3 mount, provided by **astroshop.eu**, is a unique mount that can help track the motion of objects in the night sky in the Northern Hemisphere, making it ideal for long-exposure and wide-angle astrophotography shots. Better yet, the mount doesn't require a portable power source and features a completely mechanical clockwork mechanism, simply wound up by hand.

The impressive clockwork mechanism helps track the movement of the stars for up to 60 minutes and – for cameras and telephoto lenses up to about 300mm (11.8 inches) – offers the chance to take some spectacular photographs of the glimmering night sky. The mount doesn't take up a lot of room either, allowing you to store it in a backpack and pulled out whenever opportunity strikes. With the smooth camera motion that this fully mechanical mini-mount provides, astrophotography has never been so easy.

omegon

To be in with a chance of winning, answer this question:

What is the brightest star in the sky after the Sun?

A: Arcturus **B:** Vega **C:** Sirius

Competition ends on 8 October 2020

Enter online at **spaceanswers.com** or by post to
All About Space competitions, Quay House, The Ambury, Bath, BA1 1UA

Visit the website for full terms and conditions at **futureplc.com/terms-conditions/**

PLANET NINE CONTROVERSY

THE SOLAR SYSTEM'S BLACK HOLE

Reported by James Romero

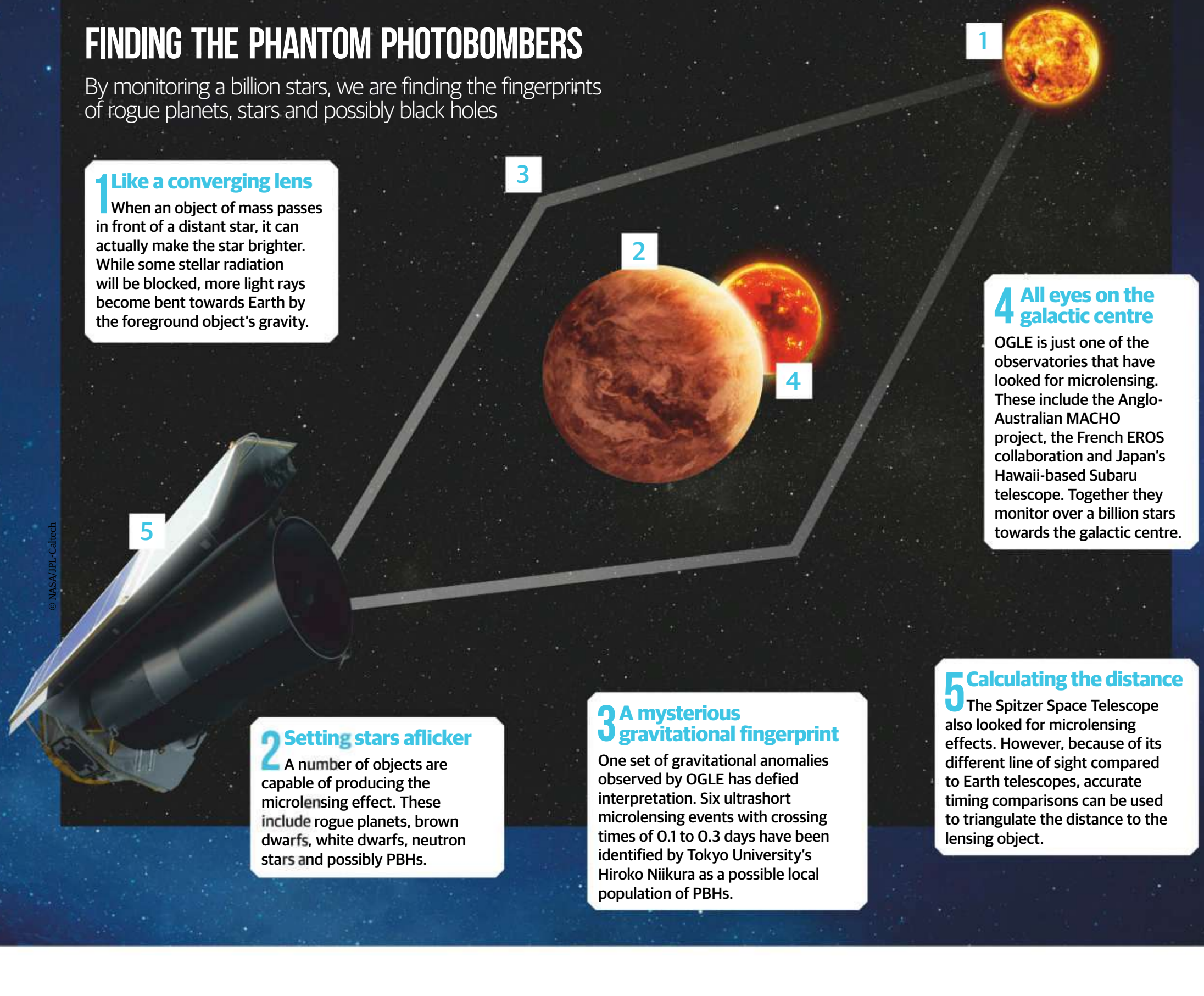
As the hunt for a mysterious world at our solar neighbourhood's edge steps up, something more exotic might also fit the bill

It's been four years since Mike Brown, the astronomer who removed Pluto's status as a planet, added a hypothetical one back in to explain strange orbits in the outer Solar System. In another two years the Vera C. Rubin Observatory will map those celestial backwaters to help find Brown's Planet Nine. But what if this target can't be seen? It's a possibility that hit the headlines last year when Planet Nine was replaced, at least in excited media headlines, by an ancient black hole. Brown himself addressed the possibility, writing on Twitter: "P9 could definitely be a black hole, as long as it is the right mass. In fact, it could also be a six-Earth-mass hamburger." So is a black hole lurking in the outer Solar System a statistical possibility worth considering? Or a whopper of a stab in the dark?

© Tobias Roetsch

FINDING THE PHANTOM PHOTOBOMBERS

By monitoring a billion stars, we are finding the fingerprints of rogue planets, stars and possibly black holes



© NASA/JPL-Caltech

1 Like a converging lens

When an object of mass passes in front of a distant star, it can actually make the star brighter. While some stellar radiation will be blocked, more light rays become bent towards Earth by the foreground object's gravity.

2 Setting stars aflicker

A number of objects are capable of producing the microlensing effect. These include rogue planets, brown dwarfs, white dwarfs, neutron stars and possibly PBHs.

3 A mysterious gravitational fingerprint

One set of gravitational anomalies observed by OGLE has defied interpretation. Six ultrashort microlensing events with crossing times of 0.1 to 0.3 days have been identified by Tokyo University's Hiroko Niikura as a possible local population of PBHs.

4 All eyes on the galactic centre

OGLE is just one of the observatories that have looked for microlensing. These include the Anglo-Australian MACHO project, the French EROS collaboration and Japan's Hawaii-based Subaru telescope. Together they monitor over a billion stars towards the galactic centre.

5 Calculating the distance

The Spitzer Space Telescope also looked for microlensing effects. However, because of its different line of sight compared to Earth telescopes, accurate timing comparisons can be used to triangulate the distance to the lensing object.

Answers are out there among trans-Neptunian objects (TNOs). Ancient debris left over from planet formation, the TNOs were swept up by a young, migrating Neptune and dumped far from the Sun in the Kuiper Belt. The ice giant's hold on this ring of rubble continues today, though its influence has changed. Once the source of gravitational chaos, Neptune now brings order to the Kuiper Belt. Any resident knocked out of the orbital plane is brought into line. "TNOs are really interesting because they explore the outer reaches of the Solar System, but they're partially driven by Neptune, which gives them a little kick," says Jakub Scholtz of Durham University. "These kicks randomise them in such a way that they should look pretty uniform."

It was the lack of uniformity that made Brown and his California Institute of Technology (Caltech) colleague Konstantin Batygin's discovery so intriguing. Six TNOs with similarly tilted orbits were all found pointing in a similar direction. Worldwide headlines followed when the culprit was identified as a five to ten Earth-mass planet. The theory raised questions, primarily about what a large planet was doing out there. Observations of other planetary systems have shown building materials that far out in short supply, ruling out in-situ formation. Was Planet Nine another reject from the inner Solar System, or a captured interstellar wanderer?

Scholtz doubts the ejected planet scenario, however, as a single gravitational kick simply elongates a planet's orbit. Its closest approach would still stay roughly the same unless you can account for a series of kicks, which is significantly less likely. The other major question was more obvious. If Planet Nine was a victim of cosmic piracy, where is the stolen bounty?

This was always going to be a challenging hunt. Planet Nine is thought to be several times the size of Earth due to the observed influence, but it's way out there, at least ten-times further than Neptune. Leading the search in recent years has been the Dark Energy Survey, which maps the Kuiper Belt looking for unexplained gravitational influence. Meanwhile NASA's Backyard Worlds project posts images from the Wide-field Infrared Survey Explorer (WISE) for the public to search themselves.

Neither have found their prime target, which is why many hopes are pinned on the Vera C. Rubin Observatory. Coming online in 2021, it aims to characterise around 40,000 TNOs and scattered-disc objects. "If Planet Nine is a conventional planet,

I think it is expected to be discovered by the Vera Rubin Observatory," says Ed Witten, a theoretical physicist at the Institute for Advanced Study.

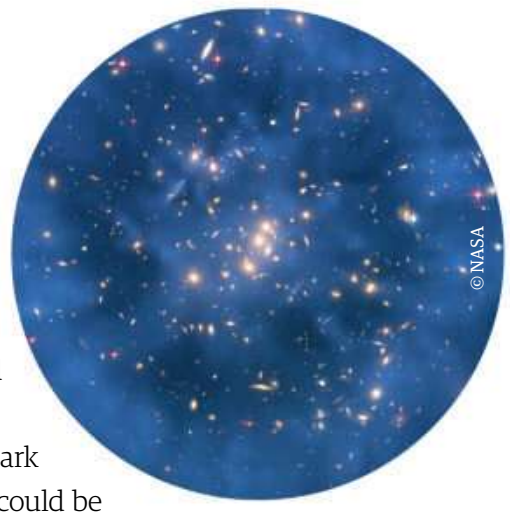
But perhaps Planet Nine isn't a planet at all. As Brown acknowledged, all we know about it is its influence on TNOs. Everything else is inferred. And while there was no reason to doubt Brown and Batygin's original suspect, a challenger emerged when Scholtz and James Unwin, assistant professor at the University of Illinois at Chicago, came across something interesting in the Chilean Andes. There the Optical Gravitational Lensing Experiment (OGLE) monitors a billion stars towards the galactic centre, looking for shadowy brown dwarfs and free-floating planets passing across the starfield.

The resulting gravitational 'microlensing' events give clues about their mysterious photobombers. However, one microlensing signature proved difficult to attribute. Ultrashort occultation events lasting just a few hours kept appearing. The OGLE team's conclusion was a local population of free-floating planets. But six nearby rogue worlds seemed a lot given the average number of planets produced per star across the galaxy.

In January last year Tokyo University's Hiroko Niikura proposed a radically different culprit: a community of nearby primordial black holes (PBHs). These were proposed by Stephen Hawking in the 1970s as a product of the early universe, when all matter was packed together. This meant random patches of slightly elevated density could frequently reach a critical level that trapped them behind gravitational points of no return. The result was huge numbers of low-mass black holes.

For a few decades PBHs were best known as a potential explanation for dark matter. Mostly because you didn't need to conjure up new particles, and cosmologist's models could produce

> "PLANET NINE COULD DEFINITELY BE A BLACK HOLE, AS LONG AS IT IS THE RIGHT MASS" MIKE BROWN


© NASA

universes full of them. However, in recent decades OGLE and other microlensing surveys have dashed those hopes by drawing blanks for many critical proposed PBH masses. "There's still some window," says Kathryn Zurek, a dark matter theorist at Caltech. "They could be 10 per cent or 20 per cent of dark matter, but you're not driven to them as a candidate in comparison to 20 or 30 years ago."

While the dark matter mystery remains, Niikura's paper claimed a local PBH population of 0.5 to 20 Earth masses could reproduce OGLE's six ultrashort microlensing events. For Scholtz and Unwin, that familiar mass range immediately caught the eye. "As physicists we're trained to think there are no coincidences," says Scholtz, who wondered if one of Niikura's black holes was lured into the Solar System to warp TNO orbits. It's an intriguing scenario, not least because it replaces our ninth world with something far smaller.

To investigate their idea, Scholtz and Unwin compared capture probabilities for rogue planets and pocket black holes. In a paper posted last September they took a number for rogue planets

Above: For decades PBHs were best known as a potential explanation for dark matter

Below: The OGLE observatory looks for the fingerprints of free-floating planets passing across the starfield

© NASA

RESIDENTS OF THE OUTER SOLAR SYSTEM

What else lies in this cold region of space?

Pluto

Perhaps the most famous resident of the Belt, Pluto is the largest and most massive member. It is also the most studied, thanks to the New Horizons probe.

© NASA

Sedna

Sedna has an extreme orbit that ranges from 76 AU to over 900. While Planet Nine doesn't explain Sedna's orbit, it could provide the buffer that kept it from being ejected.

© NASA/JPL-Caltech

Haumea

Though not directly observed, Haumea is thought to be an ellipsoid world. In October 2017 astronomers announced the discovery of a ring system, the first around a trans-Neptunian object.

© José Antonio Peñas (SINC)

Eris

About the same size as Pluto, this dwarf planet and its small moon Dysnomia orbit three-times farther from the Sun. Its high-eccentricity orbit means it was likely scattered by Neptune.

© ESO

2012 VP$_{113}$

A minor planet with the farthest closest approach to the Sun in the Solar System, this extreme TNO's orbit was interpreted as evidence of Planet Nine.

© NASA/JPL-Caltech

Makemake

Orbiting at a highly inclined 29 degrees to the plane of the Solar System, Makemake's orbit lies far enough from Neptune to remain stable and free from perturbation from the ice giant.

© ESO

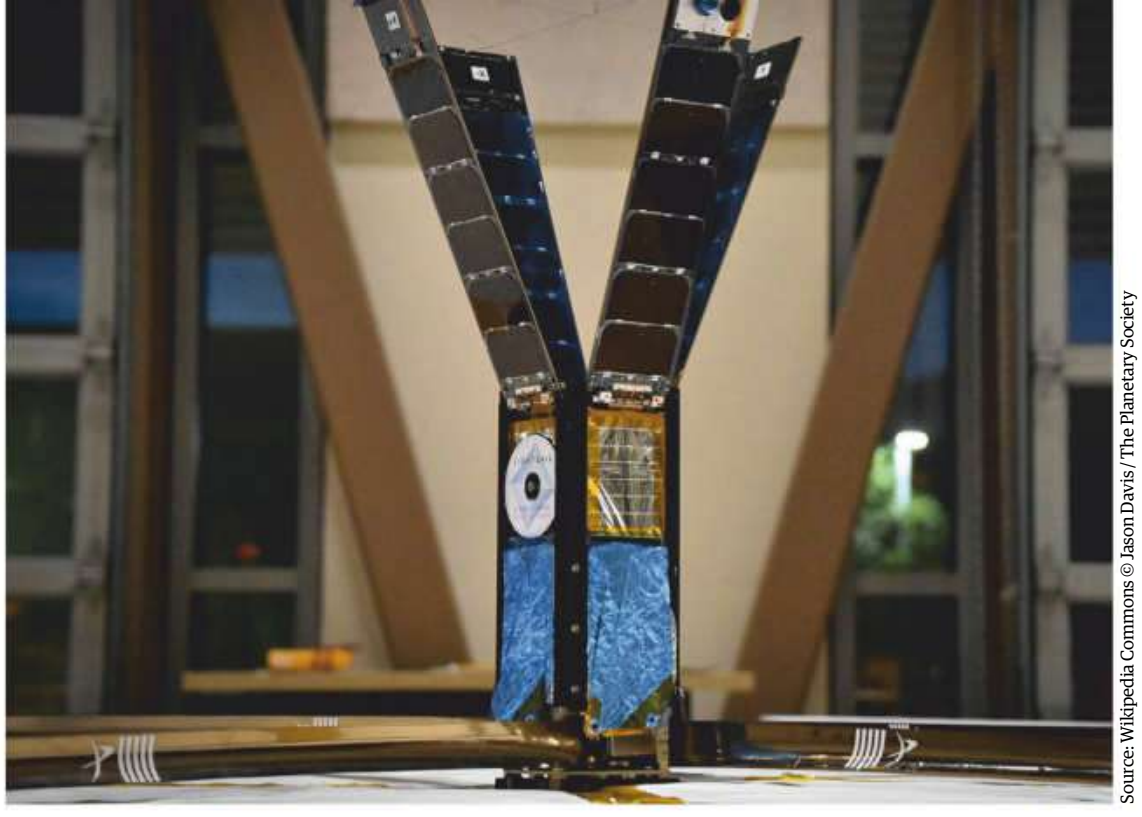
passing through our Solar System based on planet production and ejection per star, and one for the population of PBHs predicted by OGLE. They applied these to a 2017 model from Nadav Goulinski at the Israel Institute of Technology which allows you to throw bodies of various mass and velocity at our Solar System to see what sticks.

Goulinski's model highlighted two points: rogue planet capture is rare, but black hole capture is rarer still. While the model suggests a quarter of a kilometre per second as a top-end velocity for capture, rogue planets travel at the velocity of their parent stars, at around 40 kilometres (24.9 miles) per second. PBHs are thought to move at the velocity of cold, collisionless dark matter, expected to be several times faster again. But cosmic piracy is a numbers game, and while rogue planets are more speed matched to our Solar System, their lower frequency seems to even things up.

"I don't want to use the word miraculous, but surprisingly it almost cancels out," says Scholtz. "If you were willing to think about Planet Nine as a captured rogue planet, then given the OGLE result, you should consider thinking about it as a captured black hole." Not everyone agrees. Zeeve Rogoszinski is a planetary dynamics researcher at the University of Maryland. He questions Scholtz's dismissal of planetary ejection to account for Planet Nine's distant location, pointing to Solar System evolution models that work better with an extra primordial ice giant. The 'five-planet Nice model' includes the premise that Uranus and Neptune formed in between Jupiter and Saturn before ejection. "If you add a fifth ice giant to that scenario, it's much more likely that Uranus and Neptune would remain in our Solar System," says Rogoszinski.

Right: **Proposals to reach Planet Nine are based on lightsail technology**

Below: **The Kuiper Belt is made up of scattered debris left over from planetary formation**

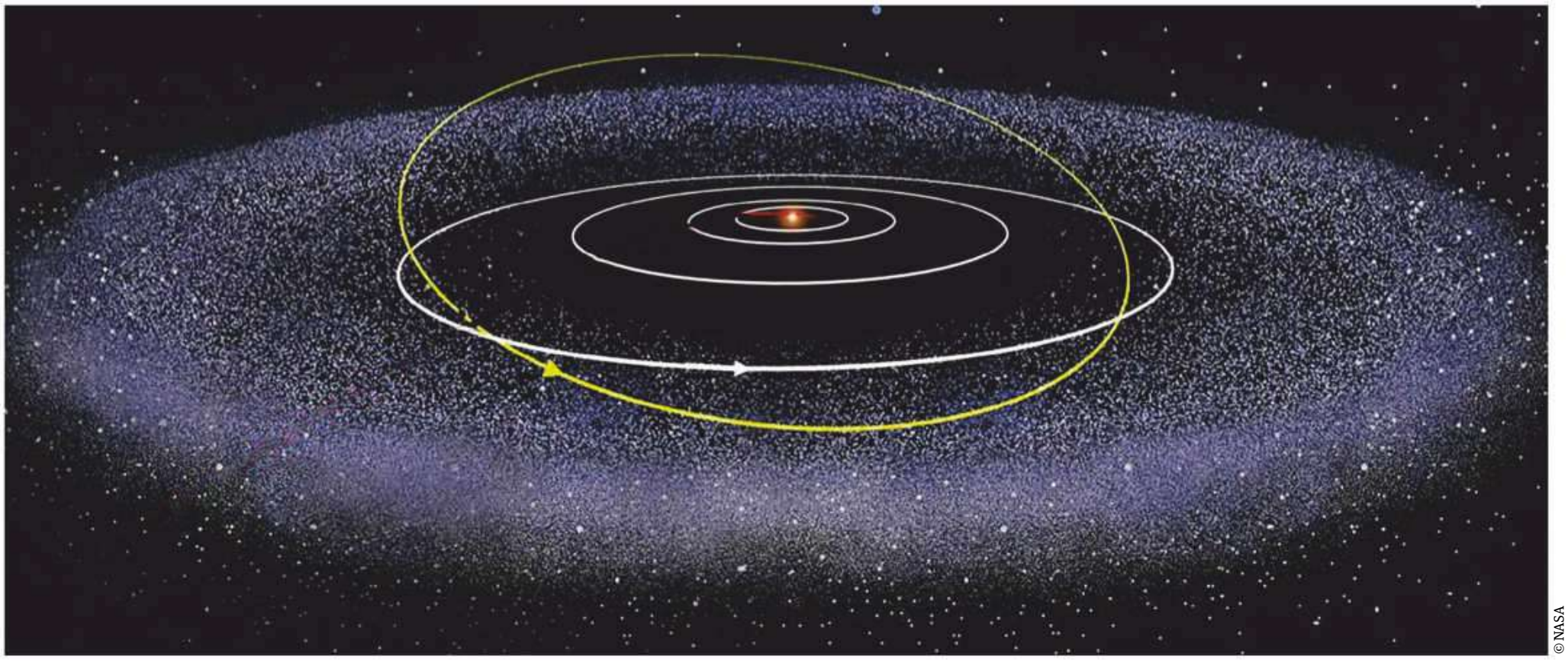


Source: Wikipedia Commons © Jason Davis / The Planetary Society

If Scholtz is right and capture is most likely, then the PBH hypothesis would clearly benefit from proof these objects exist in abundance. Niikura suggests comparing microlensing events observed towards the galactic centre – where both rogue planets and PBHs are thought to be prevalent – with data from the Large Magellanic Cloud. This local satellite galaxy is relatively depleted in planets, so the contribution from PBHs could be teased out.

Building this theoretical case seems sensible. And yet, with a potential black hole inside our Solar System, it is not surprising Scholtz's paper inspired a host of mission concepts aiming straight for this mysterious gravitational heavyweight. "It seems obvious that if there is a black hole in the outer Solar System, we want to find it," says Witten. He was first off the mark with a concept for laser-propelled, lightweight spacecraft attached to lightsails. Based on the Breakthrough Starshot concept to reach our nearest star Alpha Centauri, Witten suggested launching hundreds of craft spreading out along our Solar System's orbital plane. Unlike the Starshot craft, Witten's would carry an atomic clock and a transmitter. This additional weight would mean a decade-long journey, but would allow each craft to alert us if they encounter a planet or black hole through their acceleration.

Others proposed improvements to Witten's proposal. In his own paper Rogoszinski scrapped the weighty clock and suggested looking for bends in a craft's trajectory from the same gravitational influence. Harvard theoretical physicist Avi Loeb thought both approaches failed to address the noisy environment inside which our target likely resides. "Once you go past about a hundred AU you're battered by the interstellar medium," explains Scholtz. "For a precision mission this could be a serious hurdle."



© NASA

A BREAKTHROUGH IN REACHING THE OUTER SOLAR SYSTEM

How a mission to Alpha Centauri has inspired an approach to pinpoint our mysterious outer Solar System object

1 Light beam transportation

In the 1960s it was suggested the newly invented laser could accelerate armies of ultralight sail-bound craft a substantial fraction of the speed of light, opening up interstellar travel – or a fast way to reach the outer Solar System.

3 A perfect mirror

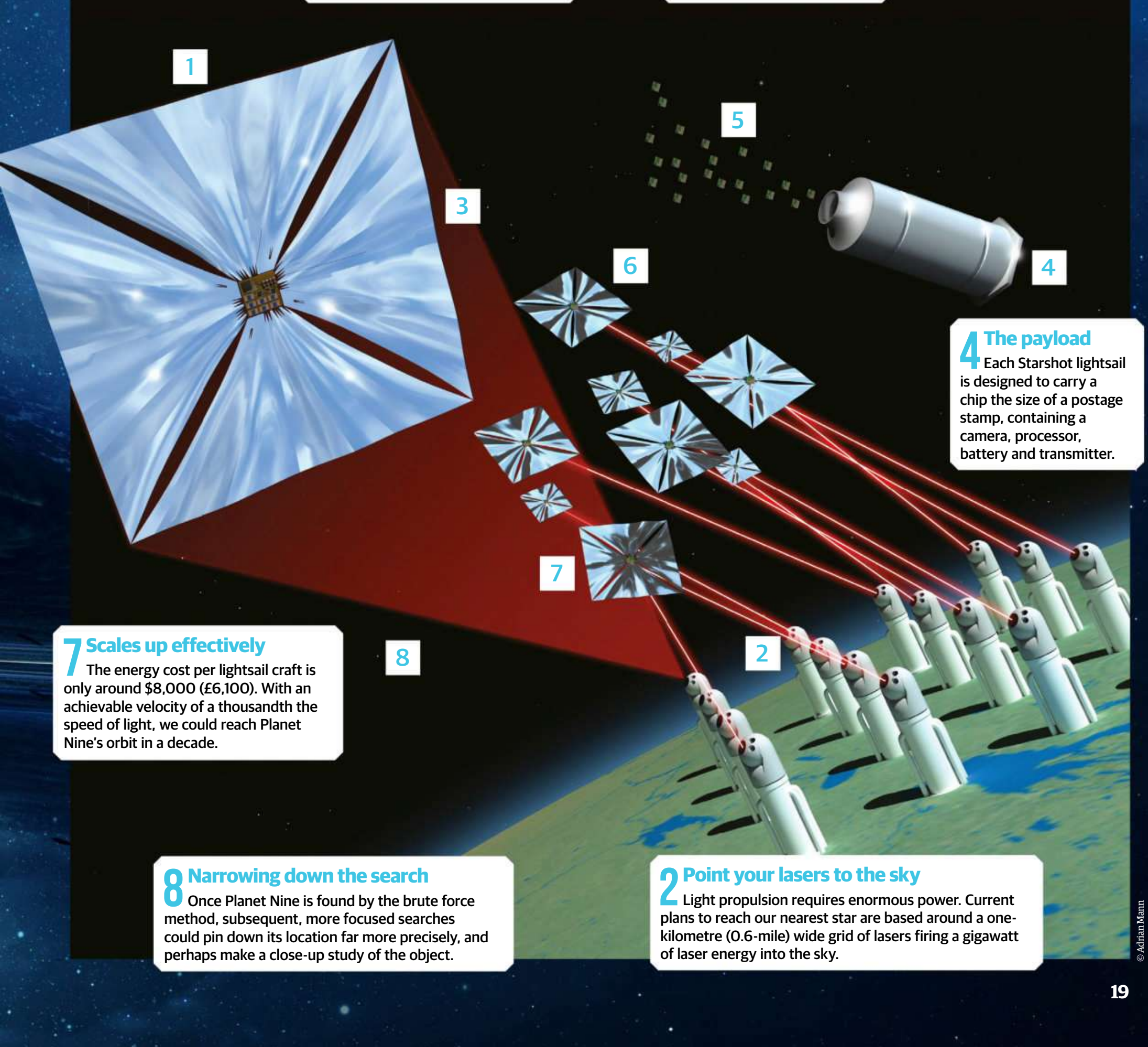
Each proposed lightsail is four metres (13 feet) across, but just a few hundred atoms thick. The sail material needs to be an almost-perfect mirror, reflecting 99.99 per cent of the photons that reach it, otherwise the lasers will burn it up.

5 Hedging your bets

With no clues where around its proposed orbit Planet Nine or our black hole might be, Starshot's safety in numbers approach to space travel would see hundreds of spacecraft launched in various directions.

6 Sensor network

In Ed Witten's Starshot-inspired proposal to find Planet Nine, each craft is fitted with an atomic clock, broadcasting time signatures. Any craft on the right path will accelerate due to our target's gravity, lengthening the gaps between signals received on Earth.



4 The payload

Each Starshot lightsail is designed to carry a chip the size of a postage stamp, containing a camera, processor, battery and transmitter.

7 Scales up effectively

The energy cost per lightsail craft is only around $8,000 (£6,100). With an achievable velocity of a thousandth the speed of light, we could reach Planet Nine's orbit in a decade.

8 Narrowing down the search

Once Planet Nine is found by the brute force method, subsequent, more focused searches could pin down its location far more precisely, and perhaps make a close-up study of the object.

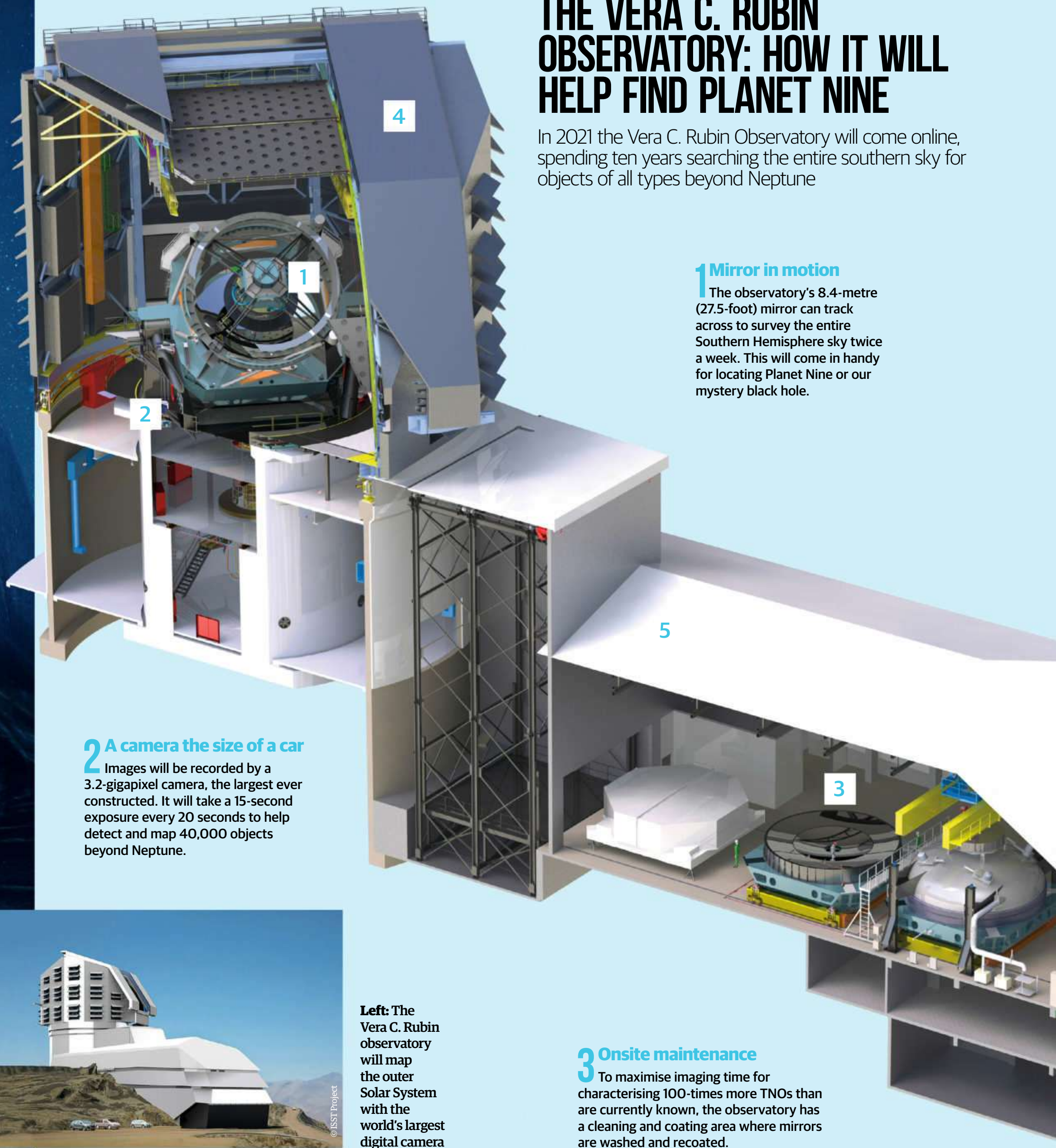
2 Point your lasers to the sky

Light propulsion requires enormous power. Current plans to reach our nearest star are based around a one-kilometre (0.6-mile) wide grid of lasers firing a gigawatt of laser energy into the sky.

© Adrian Mann

THE VERA C. RUBIN OBSERVATORY: HOW IT WILL HELP FIND PLANET NINE

In 2021 the Vera C. Rubin Observatory will come online, spending ten years searching the entire southern sky for objects of all types beyond Neptune



1 Mirror in motion

The observatory's 8.4-metre (27.5-foot) mirror can track across to survey the entire Southern Hemisphere sky twice a week. This will come in handy for locating Planet Nine or our mystery black hole.

2 A camera the size of a car

Images will be recorded by a 3.2-gigapixel camera, the largest ever constructed. It will take a 15-second exposure every 20 seconds to help detect and map 40,000 objects beyond Neptune.

Left: The Vera C. Rubin observatory will map the outer Solar System with the world's largest digital camera

3 Onsite maintenance

To maximise imaging time for characterising 100-times more TNOs than are currently known, the observatory has a cleaning and coating area where mirrors are washed and recoated.

© NASA

Loeb proposed a longer mission, sending craft weighing a kilogram or more to minimise drag. This added weight could also allow for instruments to differentiate between a planet and a black hole. However, if such a multi-decade trip doesn't appeal, a laser-shot mission will be limited to locating our elusive gravity source. Then Earth telescopes can at least focus down on a particular patch of sky where a distant planet might be teased out eclipsing background stars. "If it's a black hole the size of a baseball, we wouldn't be able to observe any occultations," points out Rogoszinski.

In the meantime, Scholtz highlights a potential signal that could tip the planet-black hole scales towards the latter. While primordial black holes disappointed as dark matter, we'd still expect one to be surrounded by the mysterious substance. Indeed, Scholtz calculated his PBH would have a five-centimetre (1.9-inch) radius and come with a dark matter halo extending out a billion kilometres. "In most scenarios dark matter can annihilate and form visible signals," says Scholtz, who suggests it's possible we've seen halo signals within observations of the Fermi Gamma-ray Space Telescope.

Though he admits it's one thing collecting this data, it's another teasing it out from its billion-photon database.

Unfortunately, whether it's dark matter annihilations, starfield occultations or spacecraft gravitational deflections, this mystery in the outer Solar System isn't giving up its secrets easily. In the absence of anything firmer, Scholtz sees the positives in the fact his theory can simultaneously explain two anomalies. Others need convincing.

"The odds are it's probably not a black hole," says Rogoszinski, who sees many reasons why this object has eluded observation without it being a tiny black hole. "Maybe its reflectance is very low, or maybe there are no stars behind it to occult?" However, he admits that if searches continue to draw blanks, at some point the probability will begin to shift. Zurek is in agreement. "I think it's probably not [a black hole], but it's not really ruled out. If there's an existing instrument, let's have fun."

Fun is one way to describe such a discovery. Scholtz goes with 'staggering' and a few other effusive terms. "To be able to experiment with the black hole, that would be a dream come true. We could really understand a lot about gravity, about general relativity, but also about quantum mechanics. It would be a new window into science."

> "IF PLANET NINE IS A CONVENTIONAL PLANET, I THINK IT IS EXPECTED TO BE DISCOVERED BY THE VERA RUBIN OBSERVATORY" ED WITTEN

4 Keeping the mirror cool

The telescope's sensitivity is maintained by cooling the mirror temperature. This could allow for the detection of flares given out if our primordial black hole consumes a passing comet.

5 At home in its environment

The observatory's orientation was selected after extensive testing to minimise air disturbance, giving some confidence that it will be able to detect brightness variations, measure TNO colour and infer composition.

© ISST Project

© ESA

Above: Eccentric Kuiper Belt orbits are often influenced by both the inner and outer Solar System

Right: The OGLE facility may have spotted the fingerprints of primordial black holes within its starfield

FISHING ON OTHER WORLDS

Could space fishing be the answer to a low-cost sample-and-return mission?

Despite a raft of probes and landers reaching the surface of far-off planets, moons, asteroids and comets, nothing quite beats having extraterrestrial samples in your hands to analyse. However, the high cost this entails has been extremely prohibitive up until now. Scientists have had to be able to find a spot to land, touch down gently on the surface, collect samples and finally have enough fuel left to escape the gravity of their landing site. This takes time, precision and money, so the quest to find a practical way to collect samples cheaply has been a high priority for a long time. Enter Professor Robert Winglee and his team from the University of Washington, who have come up with the concept of fishing for samples in space.

The idea is beautiful in its simplicity – a probe would near an object of interest, open up a tube and fire a tethered rocket to the surface of the planet or moon. This would smash into the ground, and hopefully a few metres into it. The impact would force material through an opening in the top of the harpoon, where it would be stored. The device would then be reeled back into the probe, much like a fisherman would reel in a fish. This would then be safely stored until the spacecraft's return to Earth, where researchers could analyse data with their own eyes, hands and instruments, rather than relying on machinery millions of miles away.

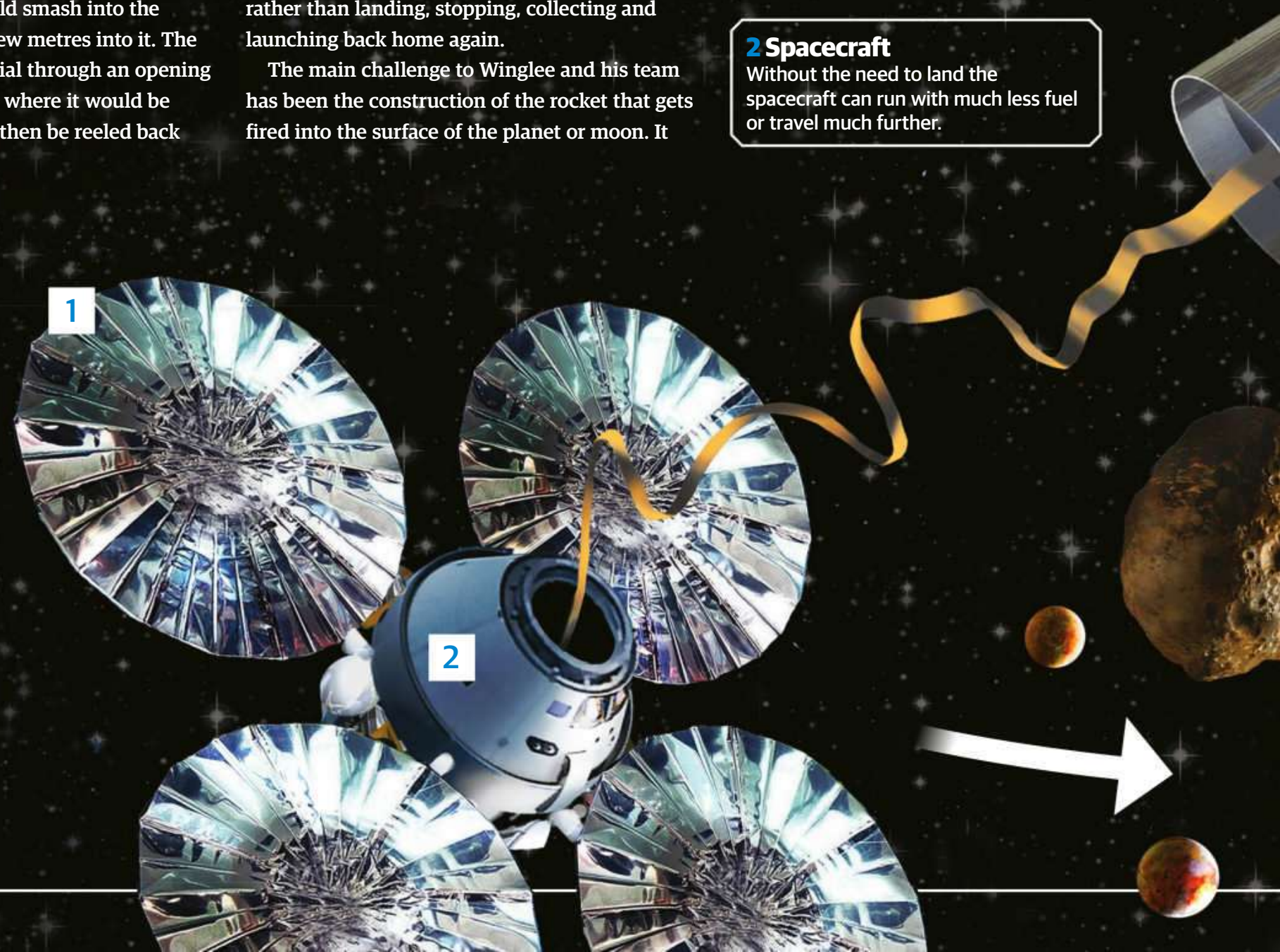
Apart from the advantage of returning data to scientists, there are a number of pluses to space fishing – mainly that the spacecraft would no longer need to land on the surface of the planet and get trapped in its gravitational field. This would mean an awful lot less fuel would be needed. Missions could be completed on a far smaller budget, or the spacecraft could travel much further before returning home.

The time taken to prepare for the mission would also be reduced, as a safe landing spot would not need to be found. The mission itself would be much quicker too, as the spacecraft would only be passing by a place of interest rather than landing, stopping, collecting and launching back home again.

The main challenge to Winglee and his team has been the construction of the rocket that gets fired into the surface of the planet or moon. It has to be phenomenally strong to withstand the force that will accompany the firing, as well as the impact as it attempts to burrow into its target. Currently it's made of steel and is able to power through 1.8 metres (six feet) of concrete, but it will have much tougher material to get through than that in outer space. The inner casing of the craft also has to withstand a huge shock and stay intact, as it will be carrying valuable samples back to Earth.

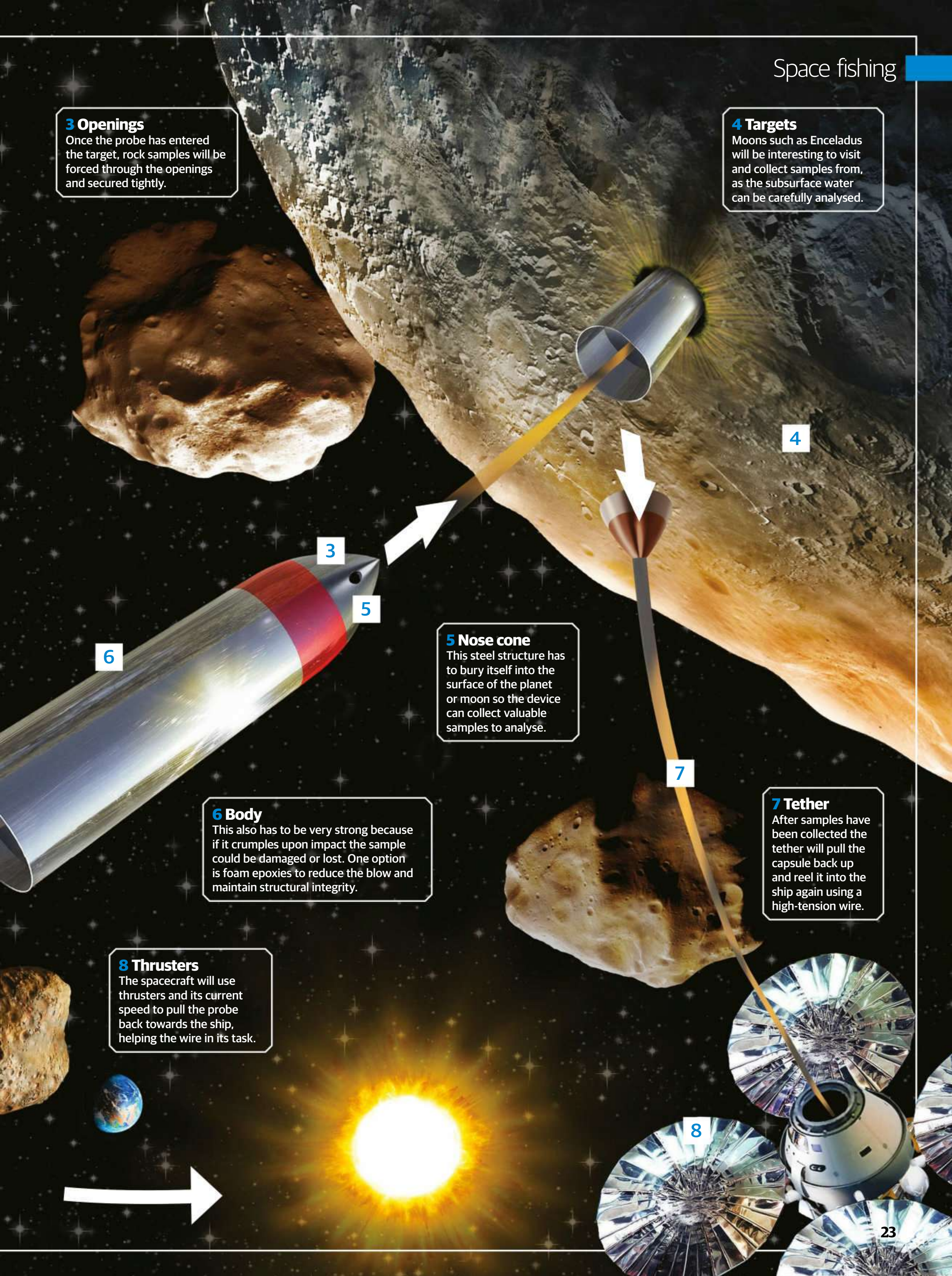
The project is currently at the Phase II stage, meaning that NASA's Innovative Advanced Concepts (NIAC) program is providing Winglee with a further £300,000 ($500,000) to enable him and his team to research this project for two more years, having already funded it so far. However, should the team succeed in their fishing mission, the financial saving and return for science on NASA's investment could be huge.

2 Spacecraft
Without the need to land the spacecraft can run with much less fuel or travel much further.



1 Analysis
One plan is for the spacecraft to be filled with instruments which will enable analysis of the samples to occur while the spacecraft is travelling.

© Adrian Chesterman



3 Openings
Once the probe has entered the target, rock samples will be forced through the openings and secured tightly.

4 Targets
Moons such as Enceladus will be interesting to visit and collect samples from, as the subsurface water can be carefully analysed.

5 Nose cone
This steel structure has to bury itself into the surface of the planet or moon so the device can collect valuable samples to analyse.

6 Body
This also has to be very strong because if it crumples upon impact the sample could be damaged or lost. One option is foam epoxies to reduce the blow and maintain structural integrity.

7 Tether
After samples have been collected the tether will pull the capsule back up and reel it into the ship again using a high-tension wire.

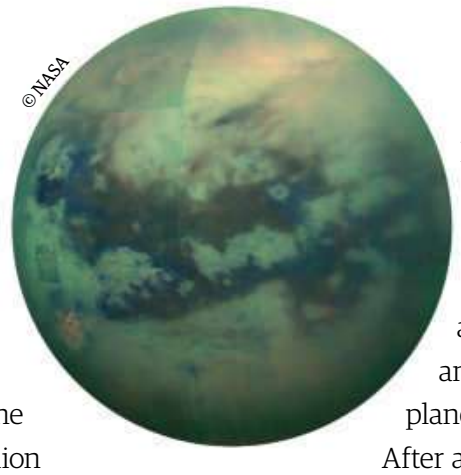
8 Thrusters
The spacecraft will use thrusters and its current speed to pull the probe back towards the ship, helping the wire in its task.

ESCAPE TO TITAN

When the Sun scorches Earth, a tiny moon in orbit around the ringed giant Saturn is our next home

Reported by David Crookes

© NASA/JPL-Caltech


©NASA

Our planet may have survived for 4.5 billion years, but humanity faces some major threats. There's always the possibility that an asteroid will wipe us out, just as one did for the dinosaurs some 65 million years ago. We could be engulfed by a gamma-ray burst or disrupted by a wandering star. There are also dangers closer to home, from volcanoes to nuclear war. Even supposing humans manage to survive all these threats, we can still say for certain that life here on Earth will eventually be no more. In around 5 billion years from now the Sun will undergo a massive change that will fundamentally alter our Solar System. It will cause the end of not only all life here on Earth, but possibly the entire planet, and we will have no choice other than to find somewhere else to live.

Astronomers have been looking at the possibilities of colonising other planets for years. Mars currently tops the list of destinations, with NASA working hard to develop the capabilities needed to send humans to the Red Planet in the 2030s. Yet some scientists are taking a much longer view. Rather than looking towards the terrestrial planets for our new home, they say humans will one day have to relocate to the outer Solar System if they want to survive. As it currently stands, sending scores of humans to live beyond the asteroid belt is out of the question. The four gas giants are utterly unsuitable for life, and the moons of the outer Solar System are well outside of the habitable zone – the region around the Sun where the atmospheric pressure is able to support liquid water, making conditions for life as we know it 'just right'.

Yet things can and will change. The Sun is getting gradually warmer, and it will eventually become so hot that it will boil off Earth's oceans. This will happen sooner than we think. "In around a billion years' time, Earth will probably no longer be habitable for humans," says Benjamin Charnay, a research associate at the French National Centre for Scientific Research from the Observatoire de Paris. "The increasing solar insulation means Earth will either evaporate all of its oceans or lose them by the atmospheric escape of hydrogen."

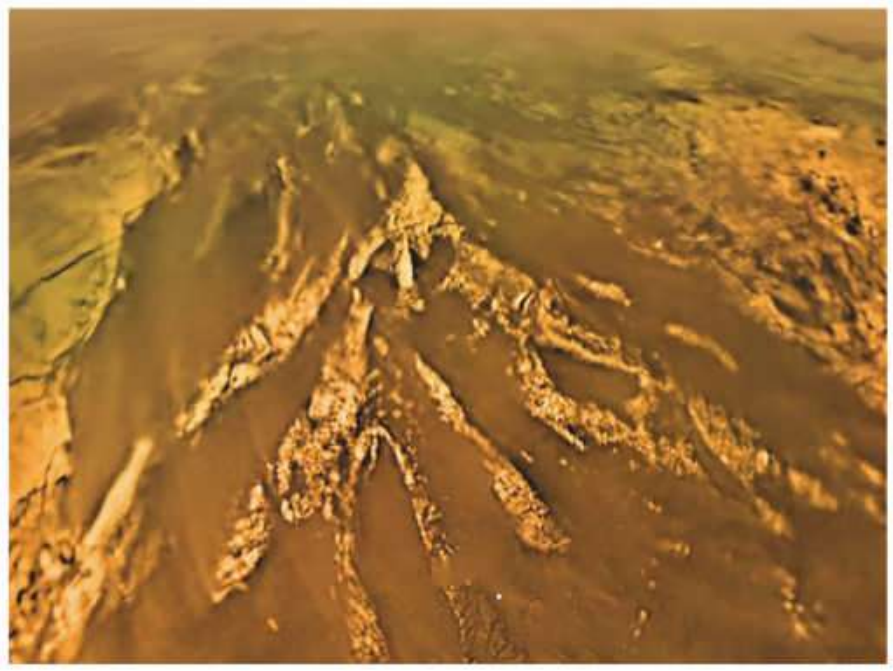
But that will only be the start. Even if humans do somehow survive the mass loss of water on Earth, the next thing to be affected would be the current habitable zone. At some stage the Sun's hydrogen supplies at its core are going to deplete, and gravity will take over. Nuclear fusion – the energy-generating process of converting hydrogen into helium – will cease, bringing an end to 10 billion years of stability. As the Sun's core collapses, helium will fuse into carbon and the Sun will bloat up into a red giant, 256 times its original size. "The Sun will swell out to beyond the orbit of Earth," says Dr Christopher McKay, a planetary scientist at NASA Ames Research Center. The effects of all of this will be devastating for both Earth and the entire inner Solar System, and at this stage staying put on our planet will not be an option.

After all, the outer layers of the Sun will now be at escape velocity and peeling away. Mercury and Venus will be engulfed, and the orbits of the planets will be widening due to a weakened gravitational pull. "Even if it survives, Earth will be inside the Sun's atmosphere," McKay adds. If all of this sounds quite gloomy for the future of humankind, then be assured that it is. "The issue for humans would be to survive to this time," says Charnay, strongly hinting that there is every chance that nobody will be around to see any of it.

Let's suppose that humans do manage to get that far. Where will they be able to go when the Sun has turned a vivid red? The smart money is on a lovely home overlooking Saturn and its stunning system of rings. In the new order of the Solar System, Titan, Saturn's largest moon, is likely to become the number one destination for humans. It won't be easy – the journey to Titan from Earth takes some seven years, which will excessively burden the body and mind of any astronaut – but it could be the perfect escape route that will keep humankind going for many more millions of years.

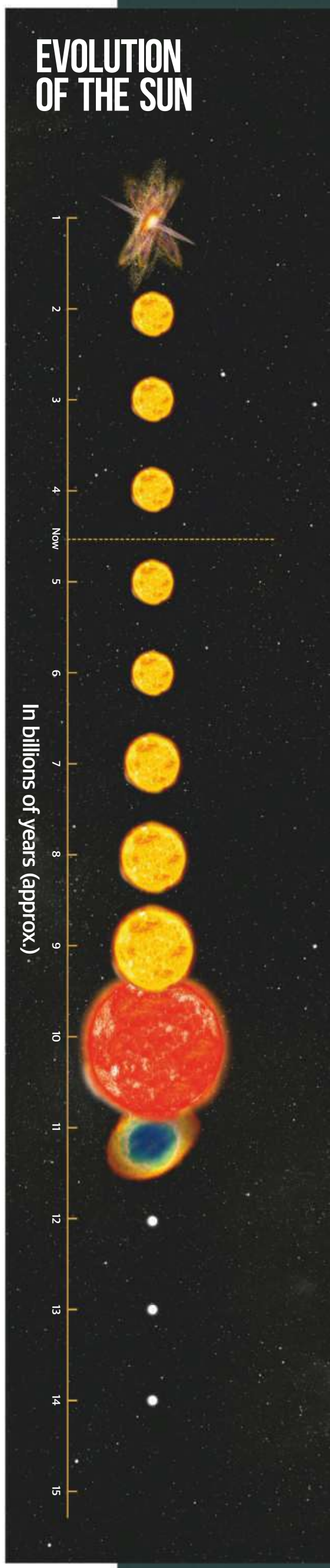
It may be hard to imagine that a moon which is ten-times further away from the Sun than Earth could possibly become a new human base, but Titan is actually a close match for our planet. In many ways it mimics Earth's primitive state. As

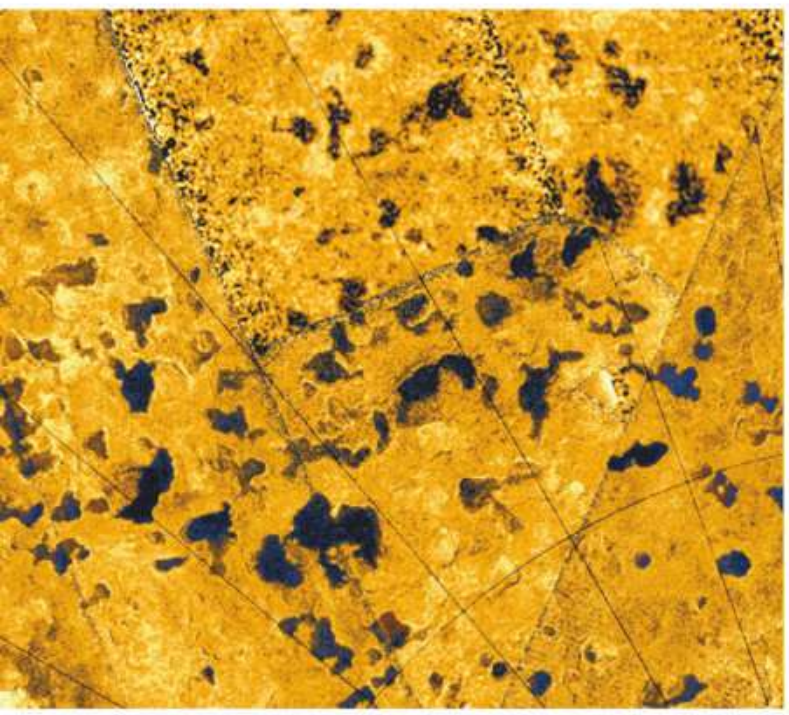
> "IN AROUND A BILLION YEARS' TIME, EARTH WILL PROBABLY NO LONGER BE HABITABLE FOR HUMANS"
>
> BENJAMIN CHARNAY


©ESA

Left: The Cassini-Huygens mission sent back up-close views of the Saturnian moon

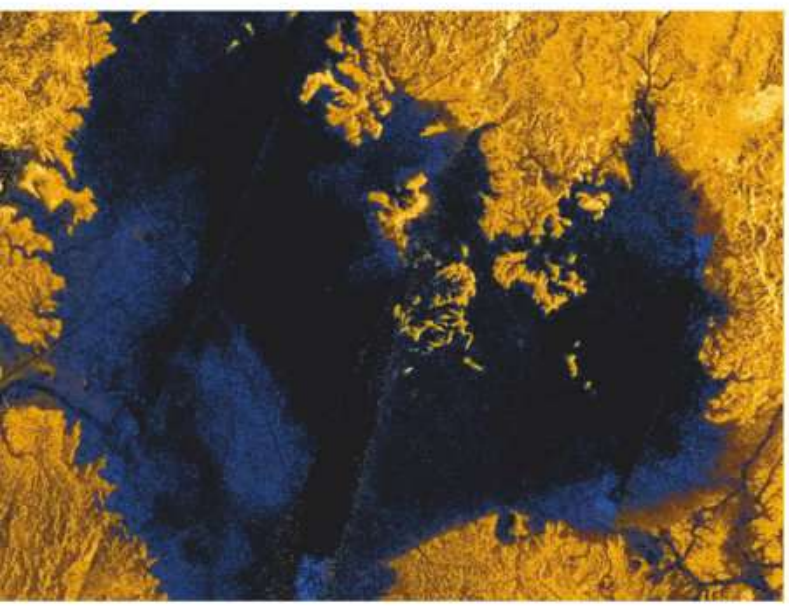
Below: Titan's water ice holds key ingredients necessary for life – they just need heating





© ESA

Left: This radar image taken by the Cassini spacecraft shows empty and liquid-filled depressions on Titan



© ESA

Below: A close-up radar image of Ligeia Mare, the second-largest known body of liquid hydrocarbons on Titan

such it has proved fascinating for astronomers who have been building up data about the moon since Huygens, an atmospheric entry probe, landed there in 2005 following a seven-year journey as part of the Cassini-Huygens mission. It was the first-ever landing accomplished in the outer Solar System, and it will not be the last by any means. When the day comes that space agencies are seeking to send manned flights to Titan, you can be assured that the technology needed to safely transport people 3.2 billion kilometres (2 billion miles) across the Solar System will be very much in place.

Titan is one of only three worlds in the Solar System with rocky surfaces and thick atmospheres – Venus and Earth being the others. "The thick atmosphere cuts down on radiation, so it is a very neutral environment," says Dr Mike Malaska, a scientist at NASA. It has a gravity that is similar to that of our own natural orbital satellite, making Titan the easiest place to fly and land in the Solar System – something that should help with future colonisation. Astronauts will be able to navigate Titan wearing just warm coats as it benefits from having zero to low pressure, unlike our Moon or Mars. "The Moon and Mars both share the problem that if humans didn't wear spacesuits they would die rapidly from depressurisation, which the movies like to show as being explosive," says McKay. "On Titan a spacesuit is not required."

Titan has weather, and it is the only body in the Solar System other than Earth to possess surface lakes and seas. It also has river channels, dunes and complex hydrocarbons, along with pebbles of ice that point to an existence of water in the past. Crucially, it has copious organic raw materials. "These would be great for colonialists to use for manufacturing things," adds Malaska. "The diversity of features on the surface suggests that there might be different patches of different types of organics – kind of like the different rock outcrops here on Earth. There might also be outcrops of water ice, so water might be available after heating it."

Indeed, astronomers say that all Titan effectively needs is warming up to make it a viable home. "Temperature is a current problem on Titan," says McKay, as the moon receives one-hundredth of the solar heat we get here on Earth. "At -180 degrees Celsius (-292 degrees Fahrenheit), if you visited today it would feel like plunging into freezing cold water, so humans would have to find a way of keeping very warm. We'd have to wear special spacesuits like the ones divers wear. Yet all this changes once the Sun becomes a red giant."

When the Sun has transformed, Titan will be in the middle of a new habitable zone, which will have moved deeper into the Solar System, taking it as far as the Kuiper Belt. The frozen moons of the outer planets will become far warmer, melting ice into liquid water and allowing life a chance to

A POTENTIAL HOME

When the habitable zone shifts, Titan could be our first destination

Titan today

What is it?

The second-largest moon in the Solar System, with a radius of 2,575 kilometres (1,600 miles).

Distance from the Sun

Titan is 9.54 AU – 1 AU being the Earth-Sun distance – from the Sun, outside the habitable zone.

Current temperature

The highest temperature on Titan is -180 degrees Celsius (-292 degrees Fahrenheit).

Titan's ice

Titan's mantle is composed of water ice, and it is likely to harbour a layer of liquid water.

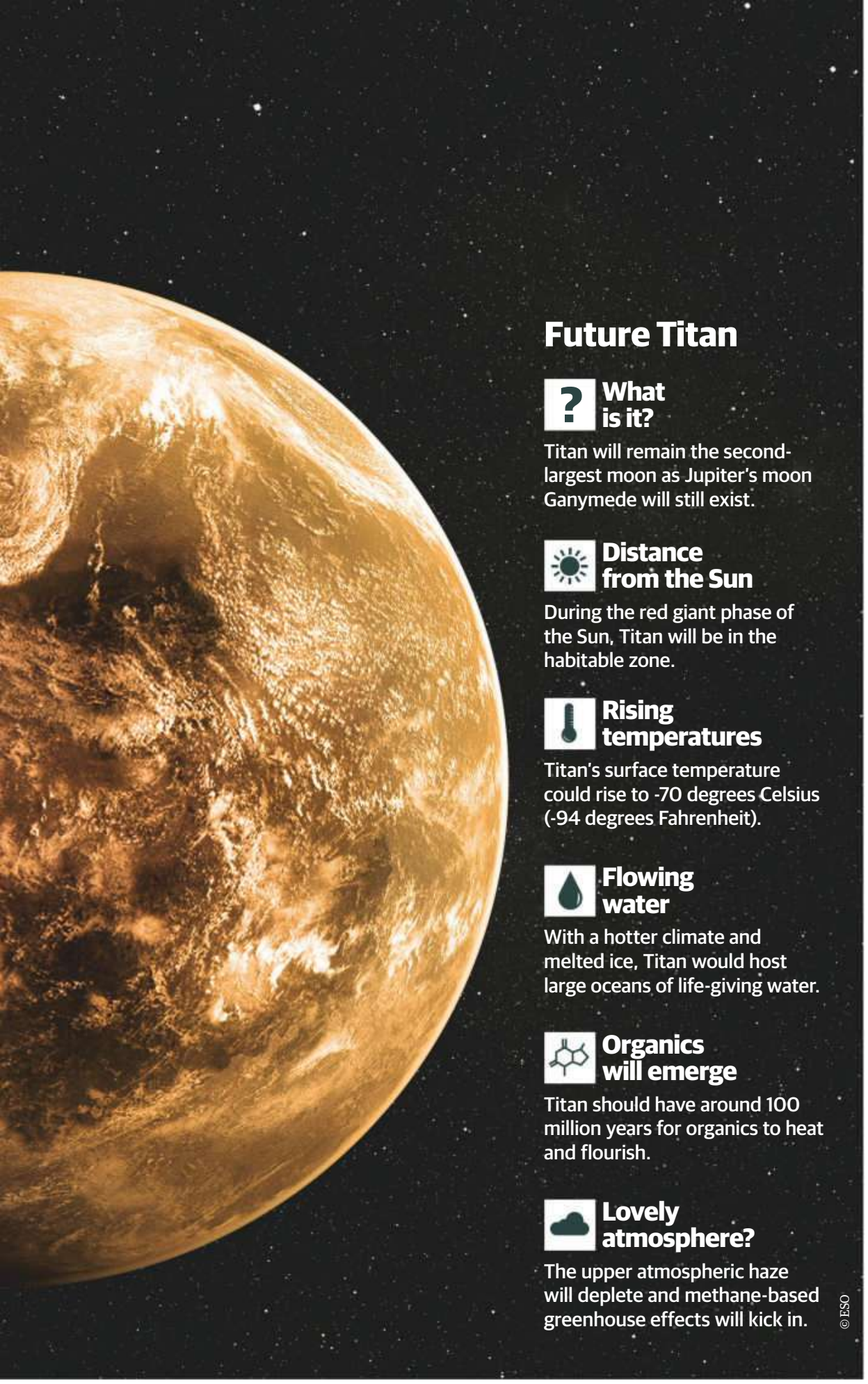
Liquid hydrocarbons

There are more liquid hydrocarbons on Titan than all the known oil and natural gas reserves on Earth.

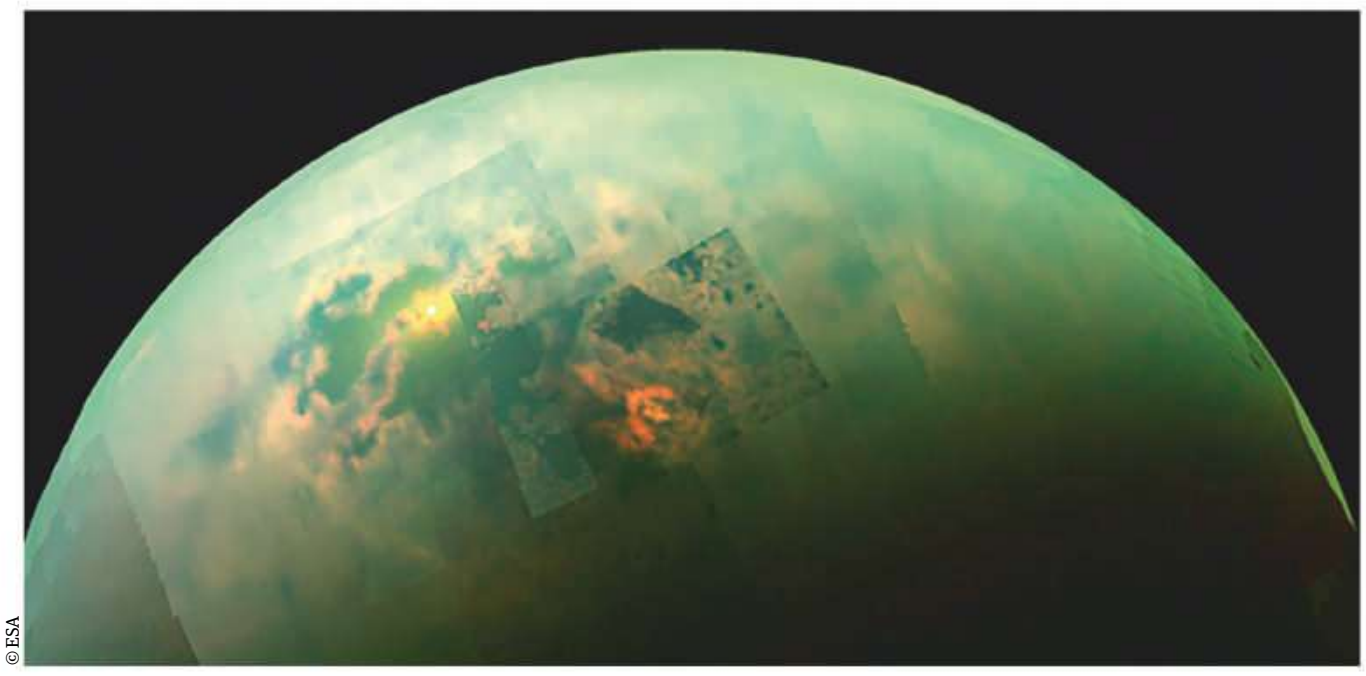
Gravity and atmosphere

Titan has low gravity and a thick nitrogen atmosphere that is ten-times larger than Earth's.

© NASA/JPL-Caltech



Below: Bright sunlight can be seen reflecting off Titan's hydrocarbon seas, which are mostly liquid methane and ethane


© ESA

"THE SUN WILL SWELL OUT TO BEYOND THE ORBIT OF EARTH. EVEN IF IT SURVIVES, EARTH WILL BE INSIDE THE SUN'S ATMOSPHERE"

CHRISTOPHER MCKAY

flourish. As McKay, Ralph Lorenz and Jonathan Lunine wrote in an important paper published back in 1997, Titan would respond well to being given a new lease of life, and humans could benefit greatly from it.

Quite apart from the Sun raising the moon's temperature to -70 degrees Celsius (-94 degrees Fahrenheit), they noted that the surrounding thick, orange haze of Titan's atmosphere would also be depleted. Since the haze currently allows the surface to be unaffected by the increase of solar radiation caused by the Sun being closer and hotter, this would enable a greenhouse effect, creating an environment that would be suitable for life. Things would begin to slot into place.

What's more, the moon's warmer temperature would also change the composition of the atmosphere. Currently it is made up of 95 per cent nitrogen and five per cent methane and "the air is thicker than Earth by a factor of seven," says McKay. But 5 billion years from now "the luminosity will be large enough to affect the icy crust and liberate a water-ammonium ocean," says Charnay. The effects will be jaw-dropping.

Dr Carrie Anderson, planetary astronomer at the Astrochemistry Laboratory at NASA Goddard Space Flight Center, says the water will melt, mix with the organics and make up amino acids, which contain carbon, nitrogen, oxygen and hydrogen – the basic elements necessary for life. "Titan has all of these," she told an audience at the Library of Congress in the US. "It's just waiting. It's ready to go."

Even so, there are still some doubts: "It would be difficult to produce an oxygen-rich atmosphere because Titan's atmosphere and interior are very reducing," says Charnay. "For instance, there is a lot of methane, which would react to destroy oxygen." There would also be something of a race against time in order for life to form and flourish. Titan will have a window of 'just' 100 million years for life to emerge, for reasons we'll come to in a moment. Anderson believes that this is sufficient time for life to form on Titan, however, making it a viable future home for humans. "At this moment in time the ice will melt in the mantle, and a lot of it should melt, so you should have liquid water. Then we have all those organics just sitting around on the surface just waiting for the Sun to heat them up," she says.

It is a prospect that also excites Malaska. "When the Sun evolves into a red giant, Titan will heat

up," he says. "The water ice in the crust will melt, and the organics on the surface will probably react with water, each other and themselves. It'll be a wonderfully interesting organic chemistry mess. Most of the organic 'goo' will be floating on the surface of the water."

And yet there is a possibility that life already exists on Titan. Malaska says life could be based on different sets of molecules and interactions, and that microscopic alien organisms may already be swimming in seas of methane. Could this have a profound effect on our ability to colonise Titan in the event of a red giant? Would questions be raised over our chances of adapting and living alongside such alien life? Time will tell, and scientists will be working on those very answers.

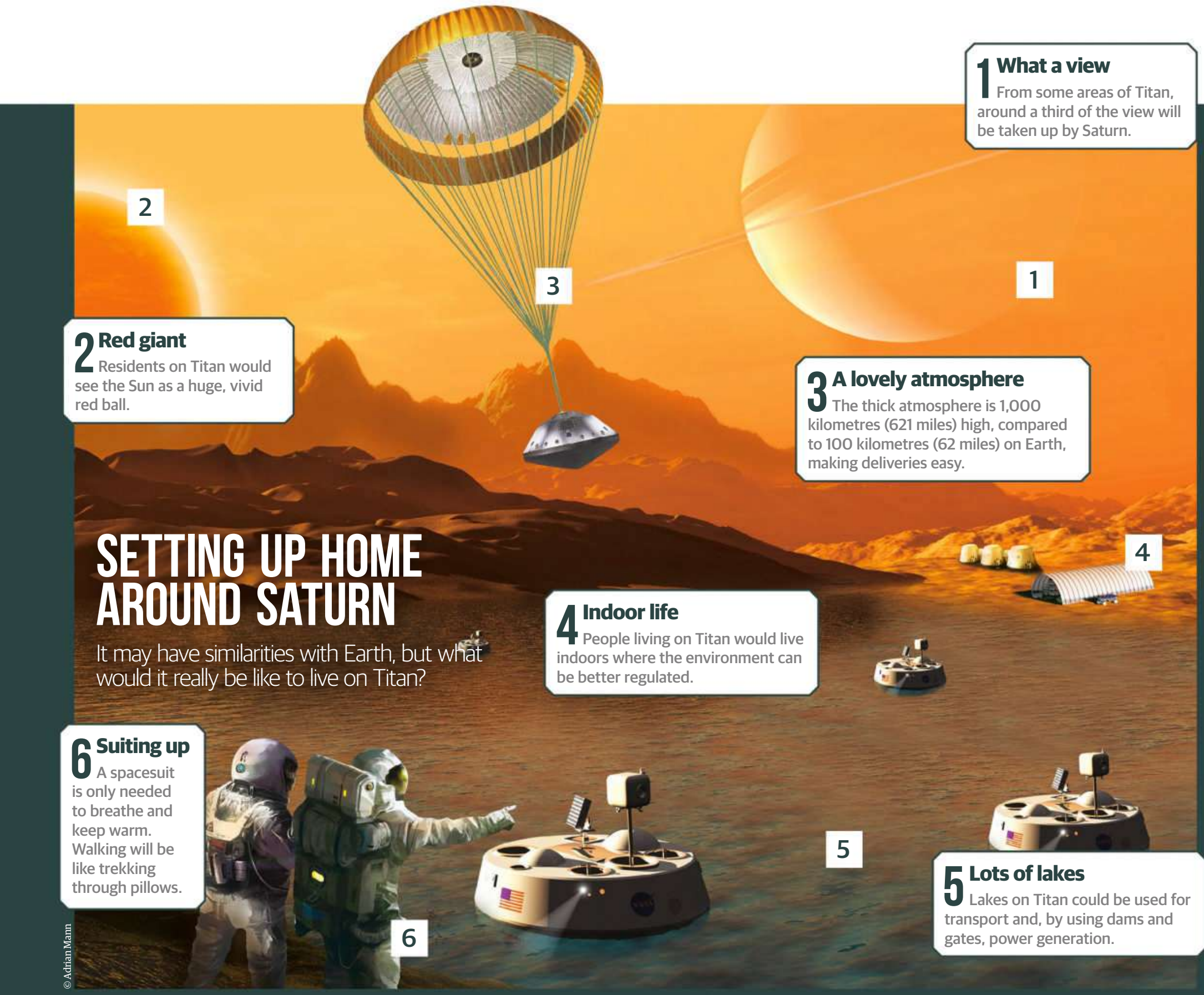
"If we discover life on Titan, it would be incredibly huge," says Malaska. "It would be a fundamentally different type of life and would take our fundamental understanding of biological processes to a new level."

He claims that Titan has already changed how we think about geology: "Comparing and contrasting the geology of Earth and Titan is a powerful tool. With regards to geology, we talk about how lakes and rivers work and now have examples using both water and hydrocarbons, so we can understand the fundamental processes even though the materials, temperatures and gravity fields are totally different.

"Discovering life on Titan would likewise change our understanding of the fundamental processes of biology. It would extend our concept of the habitable zone where surface liquids exist to a different temperature range and set of surface conditions. It would also tell us that there may be even wilder and weirder temperature and chemical regimes that we can start to think about."

But even if life exists, emerges or travels to Titan, one thing is certain: it won't be staying there forever. Any migration from Earth to Titan will always be temporary since it will start to get too close to the Sun. Once those 100 million years are up, liquid water on Titan will evaporate and the moon will suffer an incredible rise in heat.

But there is potential for a reprieve. The Sun will later contract and become a white dwarf that will burn for a billion years. This will place Titan back into the habitable zone once again. It means that any humans who escape to Titan and then suffer another setback as Titan is burned dry could – if they somehow hold out, and quite how is anybody's guess – have another opportunity for a long existence on Saturn's moon. As Anderson told her audience: "Maybe life has a real chance on Titan during those billion years." For the sake of the future of humanity, we sincerely hope it does.



SETTING UP HOME AROUND SATURN

It may have similarities with Earth, but what would it really be like to live on Titan?

© Adrian Mann

Discover the art that came before the missions.

This stunning large-format book features 200 carefully selected original NASA artworks giving the reader a glimpse of NASA history like no other.

From space suits to capsules, from landing modules to the Space Shuttle, the International Space Station, and more recent concepts for space planes, *The Art of NASA* presents 60 years of American space exploration in an unprecedented fashion.

The insightful text relates the wonderful stories associated with the art. For instance, the incredibly rare early Apollo illustrations show how Apollo might have looked if the landing module had never been developed.

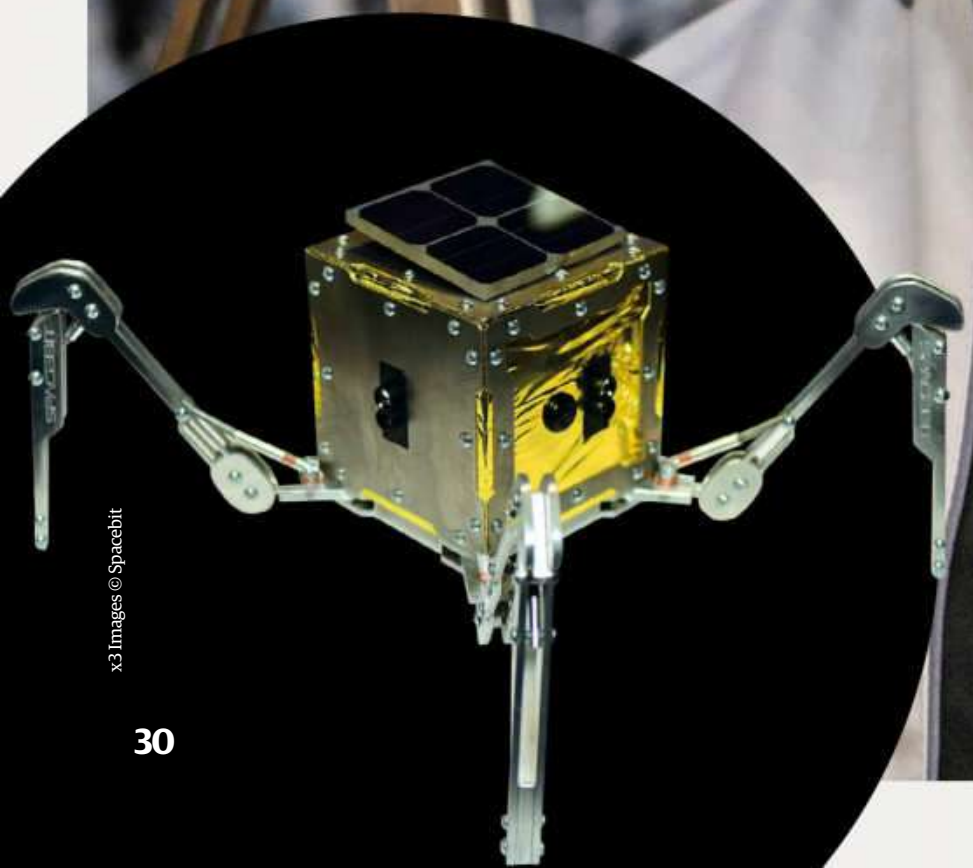
The Art of NASA is a must for all NASA fans and anyone interested in space exploration.

Available now online and from all good bookshops.

INTERVIEW BIO

Pavlo Tanasyuk

Tanasyuk is the founder and CEO of space start-up company Spacebit, based in London. The company was founded in 2014, and in 2019 Spacebit signed an agreement to send the UK's first mission to the Moon along with Astrobotic's Peregrine lunar lander. In 2021 the Peregrine lander and Spacebit's Asagumo rover will launch in an attempt to bring space exploration success to an entire nation.



x3 Images © Spacebit

2021 THE YEAR BRITAIN LAUNCHES TO THE MOON

Before humankind returns to the lunar surface, UK-built robotic spiders will be skulking across it. **All About Space** speaks to Pavlo Tanasyuk, the CEO of Spacebit, on spearheading an initiative to explore ancient lunar lava tubes

Interviewed by Lee Cavendish

For anyone looking to put the day in their calendar, when and where can we expect the launch of Spacebit's mission?
We don't know the exact date right now, but it's summer 2021. There can be a slight delay because of the supply chain. The main customer for the United Launch Alliance (ULA) Vulcan Centaur launch is Astrobotic. But we trust the ULA and Astrobotic to get us to the Moon safely and on time.

Have you mapped out where the Peregrine lunar lander is set to land on the Moon?
Lacus Mortis. It's north of the equator a little bit. It can get changed, but we expect that it will be there. The reason for that is because it's quite flat, but there is a potential lava tube in the proximity of our landing site. It's a bit of a stretch to say that we will enter a lava tube during our first mission, but that's our ultimate goal. That's why it has legs and not wheels, because it's designed in a unique way so that it can walk on rough terrain and crawl into some interesting spots.

Regarding the Asagumo rovers, these look absolutely fascinating, but in terms of engineering, what size are they, how do they move and how are they shielded from the unfiltered rays of space?
That's a good question. The size is, with the legs folded, we are talking about 16 to 18 centimetres long (six to seven inches) and about 14 centimetres (5.5 inches) tall.

No bigger than a toaster, for example?
Yes, it's basically like a nice toaster with legs, and a very expensive one. We have to protect the rover from the external environment, and that includes all sorts of radiation. It includes the Sun's radiation and its heat as well as some stronger particles.

The major concern is the balance of the temperature. It is something which is important because our rover is quite small, and we have quite a few things inside. We have a battery, we have a transmitter, we have a motherboard and a controller for the legs – it's very complex machinery in something of that size. You can almost compare it to a CubeSat in terms of size, but the rover is slightly larger. However, because the CubeSat is usually in low-Earth orbit, it's not in deep space, and the environment is not as harsh in terms of the solar rays, and therefore it's not in a thermally unstable condition.

We will have to fly through deep parts of this space, in a very cold condition. Then when deployed it's going to be heating up to roughly 75 degrees Celsius (167 degrees Fahrenheit) when we land. Probably in a couple of days it will reach above 100 degrees Celsius (212 degrees Fahrenheit). The maximum that you can get on the lunar surface is about 130 degrees Celsius (266 degrees Fahrenheit). However, once a shadow looms over it becomes cold very fast. We're trying to build lunar rovers that can withstand these deviations.

Left: Spacebit's Asagumo rover weighs in at 1.3 kilograms (2.9 pounds)

Right: Tanasyuk believes that lunar lava tubes offer the perfect protection from harsh cosmic radiation

The rover has a very unique look with its spider-like legs. How does this give you an advantage traversing the lunar surface as opposed to using wheels?

Many people were sceptical about the legs – and some of them still are. Even though we have already demonstrated it can move on the surface of Earth, we still have to prove that it can do the same on the Moon, but yes, there is some scepticism from the scientific community.

Left: Tanasyuk announced Spacebit's lunar intentions at a New Scientist Live event in October 2019

© Spacebit

But as a conceptual form it's a very interesting design because it can allow us to basically step over some obstacles. It can allow us to go in [lava tubes] at a certain angle. It can also allow us to maybe even jump on the Moon in certain conditions. It's basically like a spider. If you look at what nature has created, you don't really see anything built with wealth, and we are capable of going over hard terrain. It proves that sometimes you need legs to do certain specific tasks. If it's military combat and you need something to carry along a soldier, you can't really do that with wheels because of the terrain. The same applies to the Moon.

There are two things here to note. First of all, we're doing this because we really want to go into a lava tube, and we believe it's one of the better designs to do so. Secondly, I decided to go for this challenge because it's a cool design and I believe it's something different. It would be very obvious to go with the wheels as it's a much simpler way.

Sometimes we do regret choosing the legs because it's so much more challenging than two wheels. But it's a very interesting technology, and I believe that in our future on the Moon, and other celestial bodies, you will have robots with wheels and you will have robots with legs. That's why we have to be pioneers.

What scientific data can we expect on the return of the Asagumo rovers?

There are some limitations in terms of the size, as you can imagine, so you can't really put all the technologies inside. The instruments that the Asagumo rover will be carrying will include temperature sensors, sensors that will measure radiation and other things. We also have a small tiny laser, which will be beaming light.

The reason for this is because we want to see if there are any small particles near to the lunar surface that are charged with electricity. The only way to do it is to shoot the laser really close to the ground. That will be helpful to see if there is an atmosphere on the Moon that is really close to the surface, which scientists believe might exist.

If the mission is successful, it will be massive in terms of Britain's contribution to space exploration and science. Do you think this mission will have a profound effect on the UK space industry?

I really hope so. We're trying to create some buzz around it because we'd like to drive STEM projects and drive some larger scientific projects as well. I was born abroad, but I've been living in the UK since 2006. I came here as a student and I didn't

© ESA

Left: The future could see a human settlement on the Moon known as 'Moon Village'

Below: The Apollo missions have shown how beneficial it is to have both human and robotic explorers on the lunar surface

© NASA

know that the UK doesn't have a single rover on the Moon – or anything on the Moon for that fact. When I learned that, it was a surprise. Why? Because it's one of the greatest nations in the world and has never been able to do something like that, which is really a shame. That's why I want to correct that.

Everybody knows that the US is doing a lot at the moment, and the obvious route for everyone, including start-up companies, is to just move over to the US and take part in their missions because there is more money. But I believe that – especially with Brexit – we are in a good strategic position to progress with the future of space exploration. Lunar exploration comes first because it's closer.

In the past we used to send naval vessels around the world for trade and other purposes, and now we are more or less localised in terms of how we think. I believe that this mission could change the game, and we should be sending more spacecraft to different places on the Moon and other planets. I believe that the UK has the heritage and the spirit to do so.

You have a second mission planned for 2023. Is there anything you're able to share?

2023 is a larger mission. We will be sending a mothership, as we call it. It's going to be a larger rover, and it will host four Asagumo payloads inside. That way, even if we land far away from the lava tube, we can use our mothership rover to get there fast, and then we can use our small Asagumo rovers to go and explore. Also, you can sacrifice one of them to go and explore one of the more dangerous environments.

Lava tubes on the Moon are an unusual place to go and inspect. A lot of attention is currently focused on water ice at the lunar poles, which can be exploited as a resource. Why is exploring lava tubes so important?

Water is very important because obviously it's water. You can use it for technical aspects, such as fuel, as well as breathable oxygen. It's also easier to explain to the public. However, lava tubes are equally as important.

My belief is that in the future you will have to live on the Moon. There will be some settlements on the Moon – or as we call it 'Moon Village' – maybe by 2035 or around that time frame, so you will have to build some structures for people to live in, and it will take a tremendous amount of energy and resources to build something like that.

But if you have a lava tube, you already have an environment that is shielded from radiation and many other things. You are getting an environment where you can already store stuff, and you can live and work there. That's why one of the aspects of this mission is to help the future human exploration of the Moon. Robots and humans will be working alongside each other on the Moon, and I believe that exploring lava tubes is very important for future settlements.

From a scientific perspective it's a very interesting environment because this is an environment that has been left alone for billions of years. For billions of years there has been no sunlight, and for billions of years there has been no lunar dust. The lava tubes have been shielded from all those externalities, which is not the case here on Earth. This means it's a very good potential site for science and to learn more about the universe.

This mission will help with pre-human exploration preparation. But also it's interesting to see if any resources are there that we don't know about. But in terms of the science itself, it's very valuable when trying to learn about how the Moon formed, for example.

Is there likely to be a chance for the public, schools and universities to get involved with the mission? If so, how?

We are planning on doing a lot of STEM activities and engaging with universities and schools in the UK. Our aim is to provide a certain level of granularity of data to the schools and universities for free.

This could help students run some experiments and to learn more. Or maybe we will even allow a certain data stream live from the lunar surface so they can do some live experiments as well. We believe that this kind of STEM engagement with the new generation is what is needed.

© Astrobotic

Right: In May 2019 Astrobotic was tasked by NASA to take as many as 14 payloads to Lacus Mortis

COSMIC DUST

WHAT DOES IT REVEAL ABOUT THE UNIVERSE?

Scientists are starting to find cosmic dust all over Earth, with important consequences

When you think about space, your mind is drawn to the very big – planets, stars and galaxies. But many of the universe's secrets are hidden away in the stuff you can barely see: cosmic dust. Take our own Solar System. The gaps between the planets are peppered with tiny dust grains less than a tenth of a millimetre across. There's enough of them that if you gathered up all the dust between the Sun and Jupiter you could fashion a sphere 25 kilometres (15.53 miles) across. On a clear night, far from city lights, you can even see sunlight reflecting off these particles in an effect called zodiacal light.

According to a study by scientists including Queen guitarist Brian May – who completed his PhD on zodiacal dust in 2007 – 70 per cent of this dust was deposited by comets during their long jaunts past the planets. Roughly 22 per cent comes from colliding asteroids, with the rest thrown into the Solar System from interstellar space. Scientists have long been keen to get their hands on some of this pristine cosmic dust in order to study it up close. In 1999 NASA launched the Stardust mission, and one of its aims was to return samples of cosmic dust to Earth. These returned home in 2006, and in 2014 scientists announced that they had found seven interplanetary dust particles among the haul.

But you don't have to launch probes into space to get your hands on cosmic dust. As Earth orbits the Sun it regularly ploughs into streams of dust. These particles can strike Earth at speeds of almost 70 kilometres (43.5 miles) per second. Some of the larger grains are incinerated with such ferocity that we see them as meteors or shooting stars. Yet some of the dust survives the treacherous journey and reaches the ground.

The cycle of planetary orbit migration

The rise and fall in volume of dust hitting Earth tells us about how the planets' orbits are changing over time.

"THE COSMIC DUST COMMUNITY HAS GOT VERY USED TO PEOPLE CLAIMING TO HAVE FOUND COSMIC DUST ON THE STREET" MATT GENGE

© Getty

Ancient asteroid collisions in our Solar System

Spikes in the amount of dust locked up in ice cores tell us about asteroid collisions over the last few hundred million years.

In the past researchers have turned to places such as the pristine frozen snow fields of Antarctica, where cosmic dust grains deposited over the last million years are preserved in the ice. However, Norwegian amateur scientist and award-winning jazz musician Jon Larsen believed that even that was an extreme too far. As he read more about cosmic dust he became enchanted with the idea of finding it in the chaos of a city. He began to collect samples of sediment material from the gutters of buildings in Oslo in the hope of finding extraterrestrial interlopers hidden among it. As an amateur scientist, Larsen turned to Dr Matt Genge – a planetary scientist at Imperial College London – for advice.

"At first my advice was don't do it," says Genge. "Because over the years the cosmic dust community has got very used to people claiming to have found cosmic dust on the street, and it has always turned out to be human-made." In the dirty, busy heart of a modern city, it is a Herculean task to tease out the cosmic from the industrial. According to Genge, an average of just six cosmic dust particles fall on each square metre of Earth's surface each year. "They're on our streets, in our homes and on our clothes," he says. But Genge and his fellow researchers always thought it would be too difficult to find these small specks in urban areas. Only pristine vistas such as Antarctica or outer space would do.

But Larsen is tenacious. He used magnets to isolate microscopic particles within the debris he'd collected from Oslo's gutters and kept sending Genge images of his bounty. Eventually, after about five years of back-and-forth emailing, Larsen sent a photo that made Genge sit up and take notice.

"It really did look like a cosmic dust particle," says Genge. He invited Larsen to London to take a closer look together. In the 300 kilograms (661 pounds) of gutter material Larsen collected, he'd managed to isolate 500 microscopic cosmic dust particles. The dogged amateur scientist had shown the professionals that it was possible after all. It wasn't

DIFFERENT KINDS OF SPACE DUST

Intergalactic dust

Dying stars can blast dust out of their host galaxies and into the void between. Mergers between galaxies and dwarf galaxies can also create intergalactic dust.

What it tells us

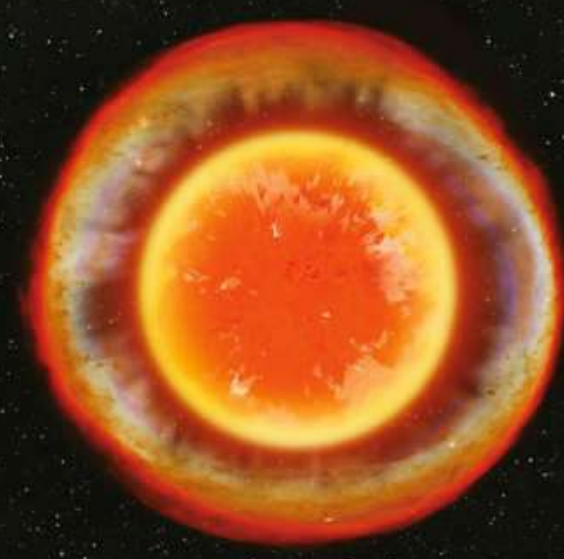
It is important to study intergalactic dust because it can dim light arriving at Earth from very distant galaxies, leading us to underestimate their brightness.

Interstellar dust

The dust between the stars is largely thrown out by supernovae as massive stars explode at the end of their lives. It is from this that new stars are formed.

What it tells us

By studying this dust astronomers hope to learn how the more complex molecules required for life first formed in the universe.



© NASA/JPL-Caltech

Left: Debris from colliding asteroids creates some of the cosmic dust falling to Earth

"DUST SEEMS TO BE ARRIVING MORE SLOWLY NOW THAN IT HAS OVER THE LAST MILLION YEARS" MATT GANGE

just Oslo either. Larsen collected samples whenever he performed in a new city, and has found space dust on the rooftops of Paris, Berlin and Houston.

From a scientific perspective, Larsen's haul is a big deal. Some of the gutters he sifted through were from commercial buildings that have their gutters cleaned regularly – perhaps as often as once a year – so the dust grains he found must be very recent arrivals on Earth. Genge compared the amount of dust being deposited on Earth now to past levels found in places such as Antarctica. "There's been a subtle change," he says. "Dust seems to be arriving more slowly now than it has on average over the last million years." Genge believes this is part of a larger cycle. Earth's orbit subtly changes shape as it is pulled on by the other planets in the Solar System. The orbits of the dust particles are also affected in this way, and so the amount of dust arriving on Earth is thought to regularly rise and fall in a repeating pattern.

Understanding this trend more clearly will allow astronomers to spot any special events superimposed on the natural dust cycle. Take an asteroid collision occurring a million years ago as an example. When the two space rocks smashed into each other they created a lot of new space dust, some of which later fell to Earth and became trapped inside rocks or encased in ice. But unless

The solution to climate change

Understanding how cosmic dust would react to initiatives such as geoengineering is crucial if we're going to successfully combat climate change.

SOME OF THE DUSTIEST PLACES IN THE UNIVERSE

Lagoon Nebula (M8)

Brand-new stars are slowly being formed as gravity pulls gas and dust together in this 100-light-year-wide nebula in the constellation of Sagittarius.

© ESO

Eagle Nebula (M16)

One of the most famous dusty places in the universe thanks to the Hubble Space Telescope, the 'Pillars of Creation' form part of the Eagle Nebula.

© NASA/ESA & Hubble

Crab Nebula (M1)

The remnant of a supernova explosion first seen in the year 1054, last year Swedish astronomers found 92 dusty globules in this famous cloud.

© NASA/ESA

The Milky Way

Look up from a dark site and you will see the Milky Way arching overhead. You can clearly see there's lots of dust between the stars.

© ESO

The Pleiades (M45)

This famous star grouping – nicknamed the Seven Sisters – contains lots of dust illuminated by the light from the infant stars.

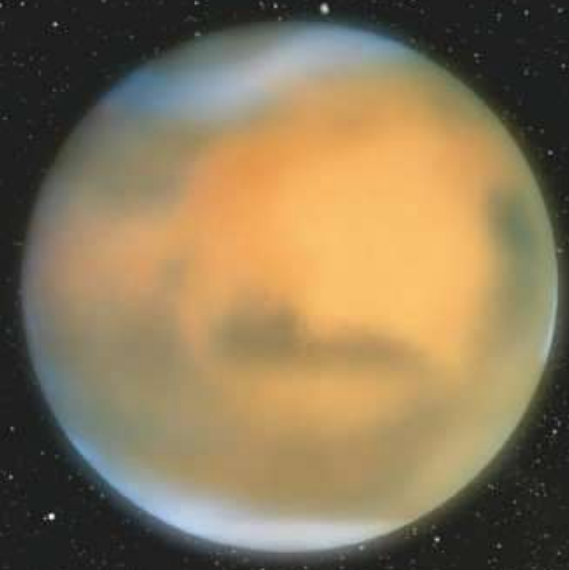
© NASA/ESA

Circumplanetary dust

In 2015 astronomers spotted a mysterious dust cloud around the planet Mars using the MAVEN spacecraft. It was 150 to 300 kilometres (93 to 186 miles) above the Martian surface.

What it tells us

This dust suggests that there's probably a process going on in Mars' atmosphere that we're unaware of.



Interplanetary dust

The dust between the planets – including the zodiacal cloud – is mostly the result of colliding asteroids or deposited by comets as they patrol the Solar System.

What it tells us

By looking for spikes in the amount of interplanetary dust arriving on Earth, astronomers can open a historical window and look at past impact events.

© Tobias Roetsch

YOU ARE MADE OF STARDUST

With the exception of hydrogen and helium, every atom in your body has stellar origins

O – Oxygen – 65%
Helps us convert food into energy via the process of respiration.

C – Carbon – 18.5%
It is found in many important compounds in the human body.

N – Nitrogen – 3.2%
A key ingredient in proteins and the bases found in our DNA.

Ca – Calcium – 1.5%
Keeps our teeth and bones strong and helps nerves function.

P – Phosphorus – 1.1%
Crucial ingredient for energy storage inside cells.

K – Potassium – 0.4%
Without potassium your nerves would not be able to function.

S – Sulphur – 0.3%
Found in both insulin and keratin – what hair and nails are made of.

Cl – Chlorine – 0.2%
Part of the gastric juices which help digest food in your stomach.

Na – Sodium – 0.2%
Found in table salt, it helps regulate your body's water levels.

I – Iodine – trace
Produced in the thyroid gland to regulate your body's metabolism.

Mg – Magnesium – trace
This element plays an important role in forming bone and muscle.

Zn – Zinc – trace
An important part of enzymes that aid in food digestion.

Fe – Iron – trace
Found in red blood cells, it helps carry oxygen around your body.

Far right: These ultra-high clouds are forming around microscopic grains of cosmic dust

Below: A close-up view of a cosmic dust particle through a scanning electron microscope

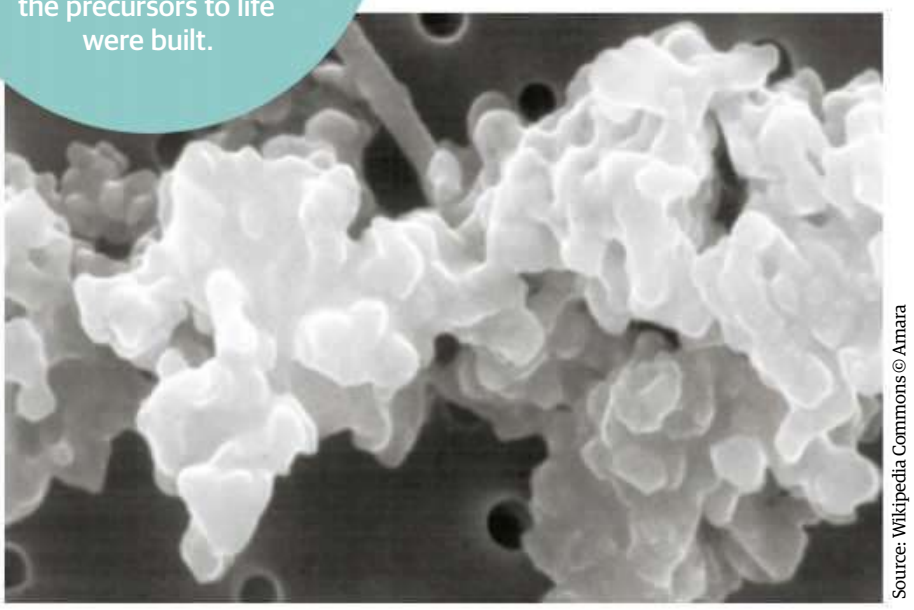
planetary scientists know where Earth was in the natural up and down of the dust cycle, they can't know for sure how much of the spike is due only to the asteroid collision. Removing the amount of background dust to see what remains would tell us a lot about the history of Solar System impacts over the last hundred million years.

But what about the dust that doesn't make it to the ground? That's scientifically valuable too. "There have been suggestions that cosmic dust in the atmosphere could affect Earth's climate," says Genge. For clouds to form there has to be some material for them to condense around. When it comes to low-altitude clouds, these 'seeds' are dust particles lifted upwards from the surface of Earth. However, this terrestrial dust can only be lofted to about 50 kilometres (31 miles). Any cloud forming higher than this must be condensing around extraterrestrial dust. These rare formations are called noctilucent clouds, and some researchers have linked them to climate change. Some researchers have even argued that cosmic dust played a role in the last Ice Age.

Yet estimates have varied wildly as to how much microscopic cosmic dust there is in the upper atmosphere. A dust detector on a satellite has previously suggested as much as 300 tonnes is being added each day. Other measurements from ground-based radar and aircraft and balloons in the lower stratosphere suggest it could be as low as 3,000 kilograms (6,613 pounds). And the difference matters. If cosmic dust is abundant, metals produced by it could be affecting the chemistry of the ozone layer. Understanding how much cosmic dust there is in the atmosphere would also help us better understand its role in climate change, and is vital in working out how best to tackle it. For example, one proposed antidote to global warming is geoengineering: adding gases to the atmosphere to help cool the planet. However, in order to do that effectively you need to know how much cosmic

How complex molecules formed in the Solar System

Dust provides a surface for other molecules to stick to. Researchers are recreating this process in laboratories to understand how the precursors to life were built.



Source: Wikipedia Commons © Amara

dust there is up there and how it will interact with the gases you add.

Between 2012 and 2017 an international team of scientists spent five years investigating atmospheric cosmic dust as part of the Cosmic Dust in the Terrestrial Atmosphere (CODITA) project. As part of their research they developed a model of cosmic dust called the Meteoric Ablation Simulator (MASI). In their laboratories they flash-heated particles with a similar composition to cosmic dust to mock up their entry into the atmosphere. They then carefully tracked the metals produced. The simulation lasts just 12 seconds, but over that period the team took 6,000 measurements. It was the first experiment of its kind.

Believe it or not, our Solar System is not the only source of terrestrial cosmic dust. Nearby supernovae explosions – the violent deaths of massive stars – can launch dust across interstellar space, into the Solar System and down through our atmosphere.

In 2016 a team of astronomers announced the discovery of iron-60 in seabed material. Iron-60 is a particularly rare, radioactive form of iron a quadrillion times more scarce than ordinary iron. More importantly, supernovae are the only place we know of where it can form. Exploding stars are littering Earth's seabeds with cosmic dust. Just as ice cores preserve it on the surface, the seabed preserves dust from past supernovae events – an important time capsule for astronomers looking to study recent explosions. You really can find cosmic dust all over Earth. As Genge said, it is on our clothes and in our homes. Larsen proved it is even sitting in our gutters. You'll find it hidden away in ice cores in Antarctica, forming clouds more than 50 kilometres (31 miles) above our heads and settled at the bottom of the sea. But we've only scratched the surface. Cosmic dust will reveal more about our Solar System's history and even far into our planet's future.

Source: Wikipedia Commons © Kevin Cho (Kee Pil Cho)

The causes of climate change

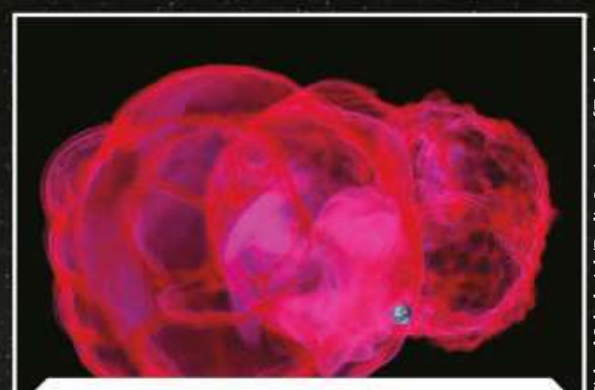
Researchers are exploring the part cosmic dust plays in the formation of noctilucent clouds and their role in global warming.

WHERE YOU CAN SEE COSMIC DUST ON EARTH

Antarctica

Cosmic dust landing in Antarctica becomes trapped in the ice and lies undisturbed for millions of years. This creates a historical record of past events.

© NASA



© Michael Schulreich/Berlin Institute of Technology

Ocean floor

Supernovae explosions can rocket dust into the Solar System and through the atmosphere to land on the ocean floor, where scientists have collected it.

Zodiacal light

While the dust itself is not on Earth, you can still see this interplanetary dust on a dark evening because it is scattering sunlight around the Solar System.

© ESO

City rooftops

Amateur Norwegian scientist Jon Larsen found cosmic dust in 300 kilograms of material rescued from rooftop gutters in multiple cities, including Paris and Oslo.

© Alamy

Focus on

DO EARTH-LIKE PLANETS ORBIT OUR GALAXY'S BLACK HOLE?

'Blanets' could form from the ice-covered dust particles that circle these cosmic colossi

Supermassive black holes (SMBHs) are theorised to be present at the centres of galaxies across the universe. They are Herculean celestial objects that consume gas and dust via an accretion disc and burp out jets of X-ray radiation from their core – jets so powerful they can be spotted from billions of light years away. This doesn't sound like a hospitable environment for planets, but recent research led by Dr Keiichi Wada, an astrophysicist at Kagoshima University in Japan, suggests it could be.

Wada and his research team believe that there could be tens of thousands of these black hole planets, or 'blanets', at the heart of the Milky Way. The formation of a planet is a complicated transition from small clumps of debris to enormous orbs of rock, gas and liquid. It's an even trickier process around a SMBH since not all of these circumnuclear discs can accommodate planet formation. These regions are far less dense than what is found around young stars, and the emissions near a black hole's event horizon can prevent gas and ice from accreting effectively.

Ice is an essential part of this formation process; it allows for debris to coalesce before the mass latches onto the sticky frozen surface. Some SMBHs only have ice orbiting them at a certain distance from their centre, where it is cool enough, known as the 'snow line'. Wada theorises that blanets can form beyond the snow line and form rocky planets – like Earth, except as much as ten-times larger – and gas giant planets similar to Neptune. These rocky blanets would take around 10 million years to come to fruition, and if conditions are right they can accrete even more debris, enabling them to evolve into gas giants.

The formation of blanets can only happen around a percentage of SMBHs, however. If a black hole is extremely powerful and active, it will have an increased radiation output that will melt ice and make it impossible for a significant amount of accretion. Think of it as throwing two pebbles together and trying to make them stick, as opposed to throwing two snowballs together.

Sagittarius A* (Sgr A*), the black hole at the core of the Milky Way, is cool enough to allow for ice in its circumnuclear disc. According to Wada's calculations, thousands of blanets are likely to have been born around it – the problem, however, is that it's extremely unlikely that we will ever observe one, since they would be hidden from sight, buried in a thick swathe of matter.

"WADA THEORISES THAT BLANETS CAN FORM BEYOND THE SNOW LINE AND FORM ROCKY PLANETS"

Above: Could supermassive black holes have planets in orbit around them like stars do?

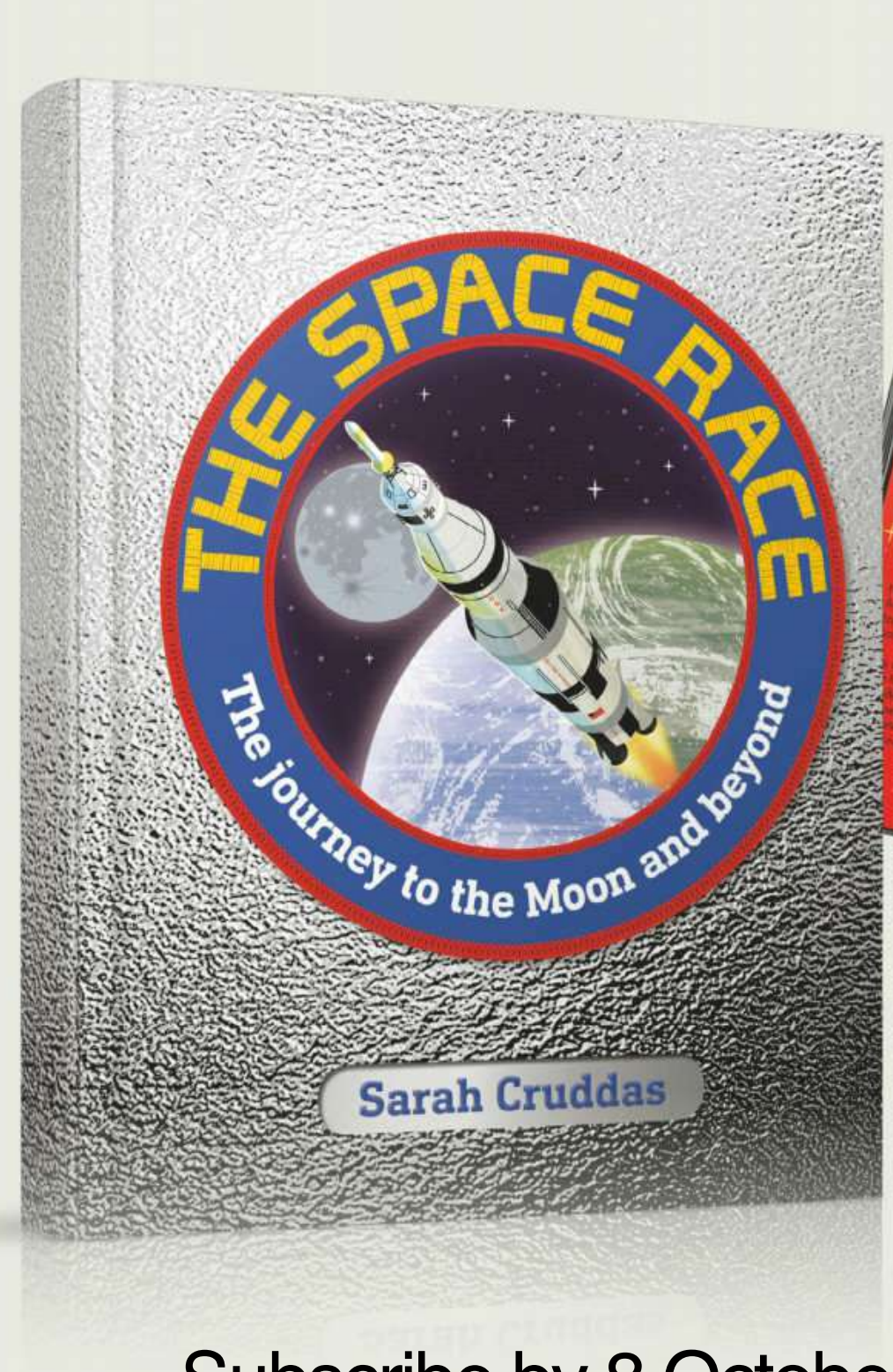
© Nicholas Forder

All About Space | Subscription offer

The Space Race

by Sarah Cruddas

FREE when you subscribe to **All About Space**



Subscribe by 8 October for our exclusive offer

"*The Space Race* reveals all of the big questions about space travel. Author Sarah Cruddas brings to life the hidden stories behind the most famous space missions before taking the reader on a journey through the future exploration of the cosmos.

"Propelled by recent scientific discoveries and printed to coincide with the 50th anniversary of the Apollo 11 Moon landing, *The Space Race* is essential to understanding every aspect of the history – and future – of human space travel."

Gemma Lavender, Editor-in-Chief

All About Space | Subscription offer

Reasons to subscribe…

- You'll never miss an issue!
- It's delivered direct to your door
- Brilliant value – great savings on the cover price
- Special subscriber covers

Subscribe now

www.myfavouritemagazines.co.uk/aas/aas108
or call 0344 848 2852 and quote AAS108

PRINT

Six-month subscription to All About Space in print plus *The Space Race* by Sarah Cruddas

PRINT & DIGITAL

Six-month subscription to All About Space in print and digital plus *The Space Race* by Sarah Cruddas

*Terms and conditions: This offer entitles new UK Direct Debit subscribers to pay just £21.25 every six months, plus receive *The Space Race* book. Gift is only available for new UK subscribers. Gift is subject to availability. Please allow up to 60 days for the delivery of your gift. In the event of stocks being exhausted we reserve the right to replace with items of similar value. Prices and savings quoted are compared to buying full-priced print issues (£5.20) and full-priced digital issues (£3.99). You will receive 13 issues in a year. Your subscription is for the minimum term specified. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) or are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: **www.bit.ly/magterms**. Offer ends 8 October 2020

DID LIFE COME FROM COMETS?

They race in and out of our Solar System, and according to evidence, they could have brought life with them

Reported by Colin Stuart

In the void between planets, huge snowballs tumble across the Solar System. These comets - relics from an age before large worlds circled the Sun - have been patrolling our local neighbourhood for 4.6 billion years. Hidden away in their icy layers are clues to what our Solar System was like all that time ago, along with teasers as to how our family of planets formed. But their real bounty could be knowledge of how one of the Solar System's stand-out features came to pass: life. Could comets have played a role in delivering biology to Earth? Scientists are starting to think so.

Perhaps the single biggest factor in our planet's suitability for life is the presence of water. Thanks to our temperate position around the Sun, water can exist largely in liquid form. Yet still fresh from the violent collisions that gave birth to it, the early Earth would have been too hot for any water molecules to escape evaporation. "The impact that formed the Moon would have gotten rid of any ocean or atmosphere too," says Kathrin Altwegg from the University of Bern in Switzerland. The fact that we live on a wet planet today suggests that more water must have arrived some time later. Given that Earth is thought to have developed oceans within 500 million years, and life is thought to have popped up within 800 million years, it must have come fairly quickly and in abundance.

Naturally astronomers turned their attention to the objects in space known to have a high water content: comets. Often compared to 'dirty snowballs', these small objects were formed far from the Sun when gravity gathered up grains of dust and ice into objects several kilometres across. Many of these comets crashed into the planets and their moons in the Solar System's youth.

By looking at the ones left over today, scientists can judge whether their lost companions were the source of most of Earth's water. "Although you'd have needed 10 million comet impacts to provide enough water," explains Altwegg. And as far back as 1986, this idea hit another snag.

Water comes in two main varieties: the ordinary water that we are used to on Earth and a rarer type called 'heavy water'. The difference is that in heavy water the two hydrogen atoms - water's composition is H_2O - each boast an extra particle called a neutron. Scientists can easily measure the ratio of ordinary water to heavy water in Earth's oceans - there are 160 molecules of heavy water for every 1 million molecules of ordinary water. If comets did indeed bring that water here, the surviving ones that didn't bash into a planet or moon should also exhibit a similar ratio today.

In 1986 the European Space Agency (ESA) sent the Giotto probe to sidle up to Halley's Comet during its jaunt through the inner Solar System. They found that heavy water is twice as abundant on the comet as it is on Earth. In 1999 telescopic analysis of Comet Hale-Bopp showed that it also has a significantly higher proportion of heavy water present than back here on Earth.

However, in 2011 astronomers used the Herschel Space Observatory to take a closer look at the Comet Hartley 2. There they found a good match between the heavy water content of the comet and Earth. Then came the ESA's famous Rosetta probe, which carried the Philae lander on a decade-long trek to Comet 67P/Churyumov-

Comet impacts formed glycine

Laboratory experiments suggest amino acids, such as glycine, may form on comets as they are struck by other flying space debris.

© Tobias Roetsch

"THE FACT THAT WE LIVE ON A WET PLANET TODAY SUGGESTS THAT MORE WATER MUST HAVE ARRIVED SOME TIME LATER"

Gerasimenko. On 12 November 2014, Philae made history by making humanity's first landing on a comet. Meanwhile, Rosetta studied the ancient ice pile from orbit. Data from Rosetta's ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) instrument backed up the Halley and Hale-Bopp findings. "The proportion of heavy water on 67P is three-times higher than on Earth," says Altwegg, lead scientist for the ROSINA instrument.

So it seems unlikely that comets are solely responsible for delivering water to our planet. "The average abundance of heavy water on comets is certainly higher than it is on Earth," comments Altwegg. That rules out comets as the dominant source of our water. However, there are two main alternative explanations. The first is that most of the water on Earth was brought here by asteroids. The second is that over time Earth itself replenished its surface water from deep inside the planet. "For me this makes a lot more sense than comet or asteroid impacts, because you would need a lot of them," explains Altwegg.

While comets might not have brought us the majority of our life-giving water, other results from Rosetta suggest these ice mountains might have played a different, yet still vital role. Altwegg and her team scrutinised the comet's coma – the dusty cloud of material that cocoons 67P as it is warmed by the Sun. Tucked away inside they found glycine, the simplest version of molecules called amino acids, which are often referred to as the building blocks of life because on Earth they link together to form proteins, the workhorses of our cells. Glycine had previously been found in dust returned to Earth from Comet Wild 2 by NASA's Stardust mission, but some researchers argued that the sample might have become contaminated during the analysis.

Some comets have similar water

At least one comet has a similar proportion of heavy water as Earth's oceans. If comets brought water, amino acids and ribose, they could form a recipe for life.

THE MAKING OF LIFE ON EARTH

Comets played a part in making our world a living planet

1 Giant molecular cloud
An interstellar gas cloud collapses under its own gravity to form a group of new stars, one of which is the Sun.

2 Protoplanetary disc
A dusty disc of material forms around the new star. Gravity slowly pulls this material together – a process that will eventually form the planets.

3 Comets form
Far from the Sun, beyond a point known as the 'ice line', smaller, icy objects – comets – coalesce.

4 Ultraviolet radiation
UV light from the young Sun could have helped form ribose on some comets, although it has yet to be confirmed with a comet sample.

5 Comet impacts
With much debris flying around the Solar System, the comets get hit hard. The force of the impact creates amino acids.

The Rosetta team also found other chemicals important for life on 67P, including phosphorus and formaldehyde – both play a key role in the formation of DNA. Other molecules known to be important in building amino acids had already been found on Halley's Comet, Hartley 2 and Hale-Bopp, but Rosetta was a step up. "We more than doubled the number of molecule types found on comets from 28 to 60," says Altwegg. But how did these molecules end up there?

Zita Martins, an astrobiologist at Instituto Superior Técnico, Portugal, believes she might have the answer: they were forged when comets were struck by other space debris. Along with colleagues including Mark Burchell at the University of Kent, she created mixtures of ices similar to those found on a comet and used a gas-powered gun to fire steel projectiles at them at seven kilometres (4.3 miles) per second in order to simulate the comet being hit. "It took us three years to get the ice mixtures right," says Burchell. "But after the impact the ices contained amino acids like glycine." They dubbed the effect 'shock synthesis'.

Comets contain amino acids

Complex molecules such as the amino acid glycine have been found on comets. Amino acids are chains of atoms that link together to form proteins: the workhorses of our cells.

Left: The Stardust capsule that crash-landed back on Earth with comet dust on board

Right: A false-colour image of the smooth Hapi region of 67P. The blue may point to the presence of frozen water ice

COMET CHEMICALS

Astronomers studying 'space snowballs' have found chemicals crucial for life on Earth

A Water

The jury is still out on the exact role comets played in Earth's water supply.

B Phosphorus

This element is crucial for forming DNA, as well as cell membranes.

C Ribose

Experiments on artificial comets have suggested that ribose could form on a comet.

D Glycine

In living things, proteins are made out of amino acids. Glycine is the simplest one.

E Formaldehyde

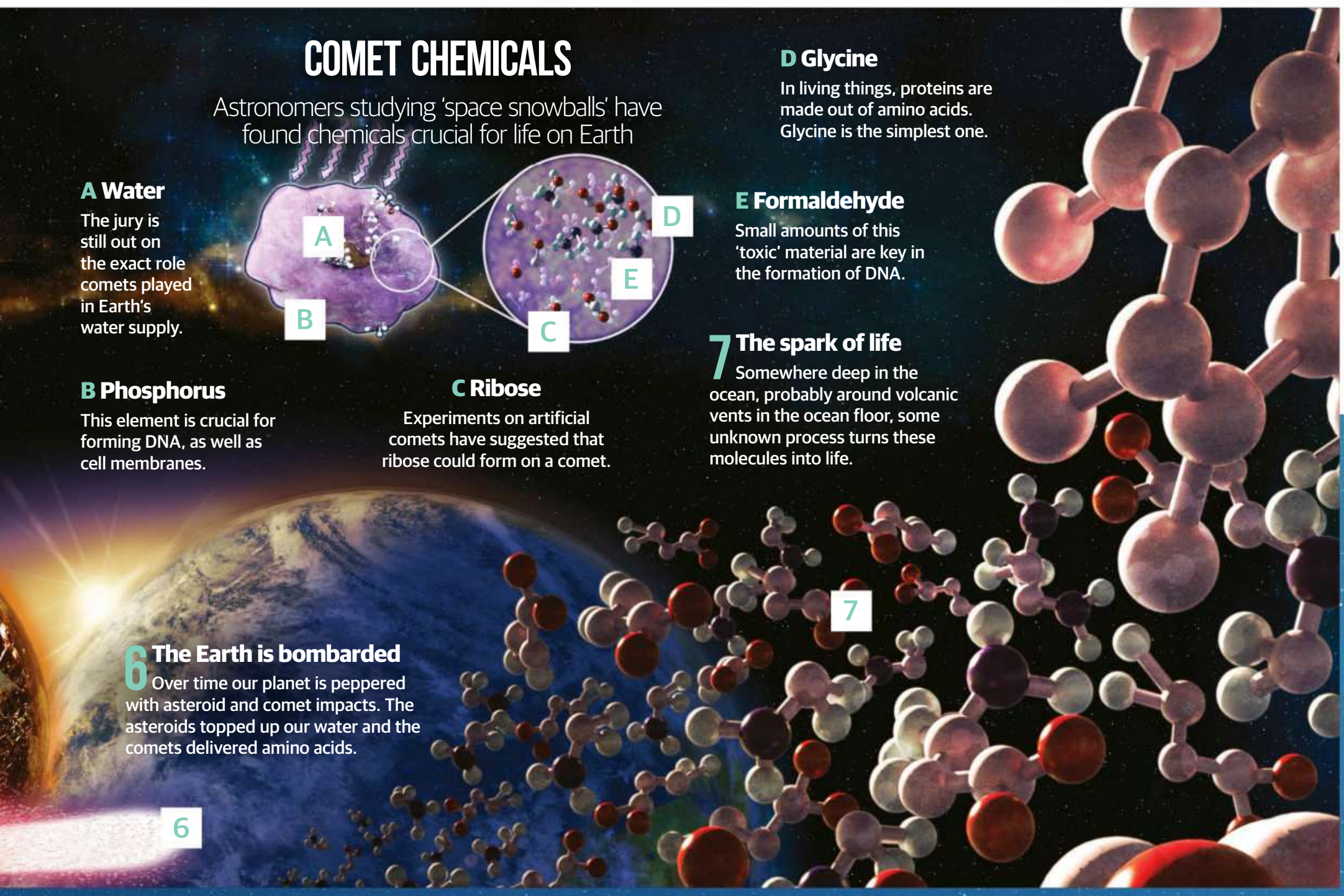
Small amounts of this 'toxic' material are key in the formation of DNA.

6 The Earth is bombarded

Over time our planet is peppered with asteroid and comet impacts. The asteroids topped up our water and the comets delivered amino acids.

7 The spark of life

Somewhere deep in the ocean, probably around volcanic vents in the ocean floor, some unknown process turns these molecules into life.



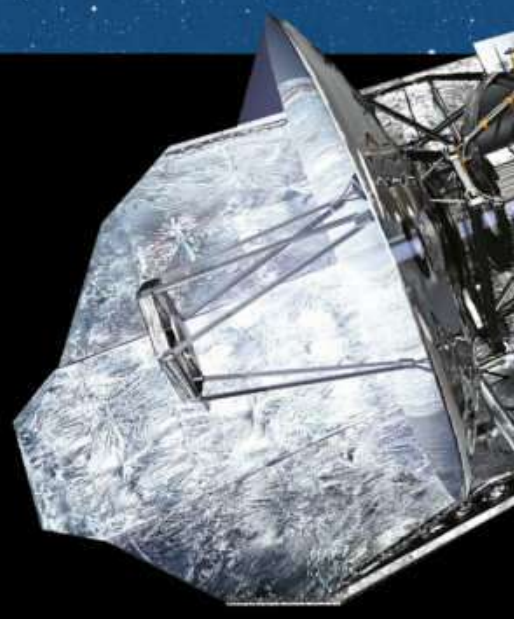
© Nicholas Forder

HUNTING FOR CLUES: MISSIONS TO A COMET

By getting up close and personal with these dirty snowballs, we've learned more about their role

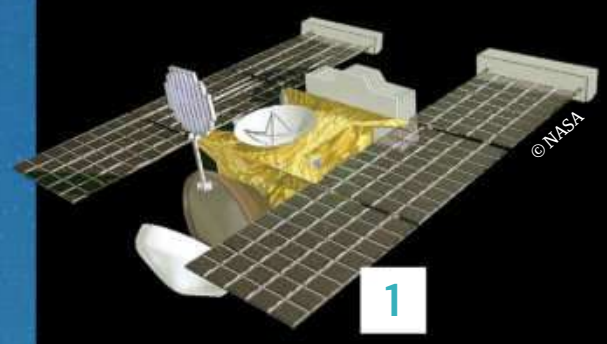
Late Heavy Bombardment

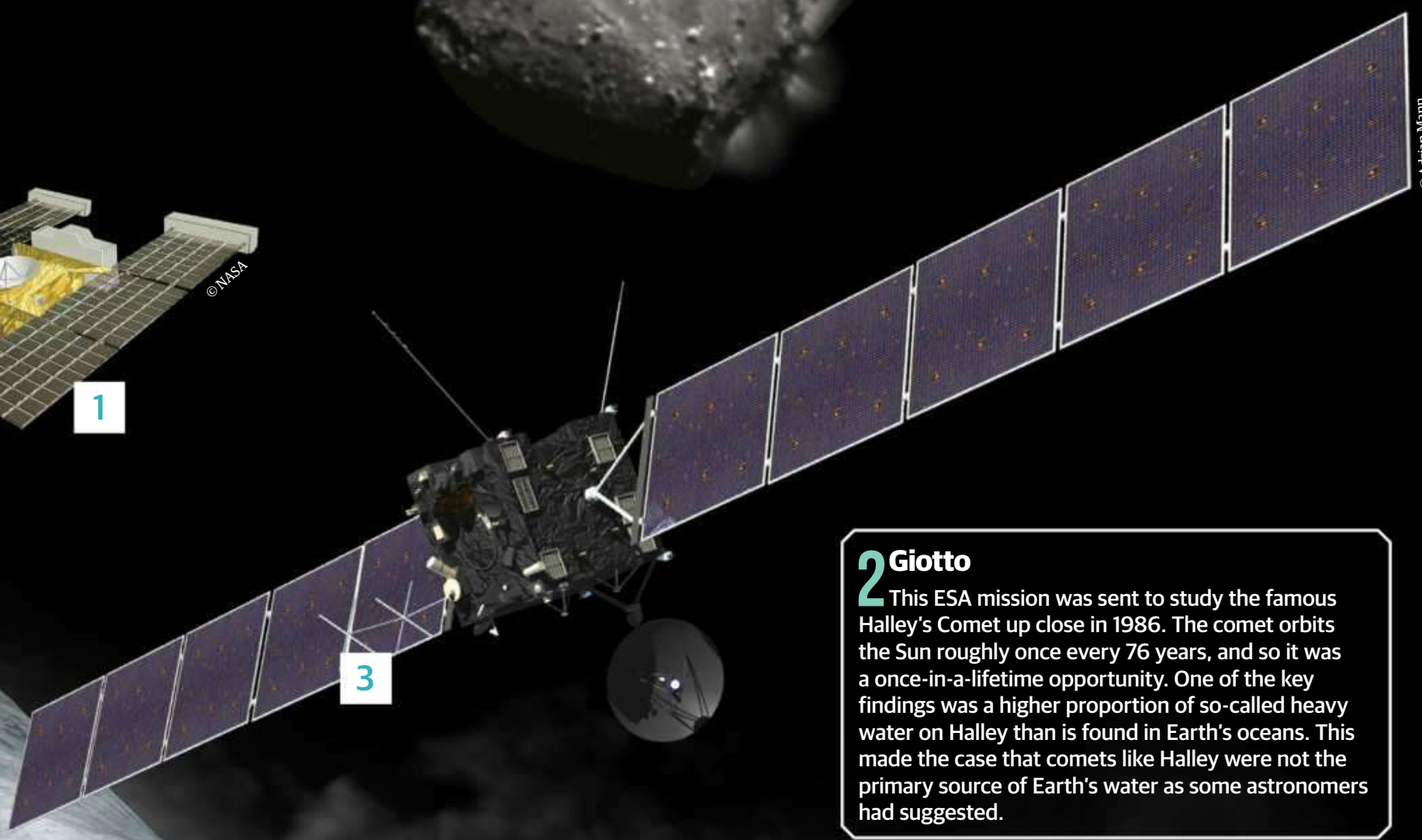
Evidence from craters on the Moon and other celestial bodies indicates that Earth was hit by a lot of impacts around 4 billion years ago.



1 Stardust

This audacious NASA mission was sent to return a sample of Comet Wild 2 to Earth. Launched in February 1999 and rendezvousing with its quarry in 2004, it successfully returned the sample home in 2006. Initial analysis found it contained the amino acid glycine, although some researchers had suggested the analysis might have contaminated the sample, even though the clean room used for the experiment was 100-times cleaner than a hospital operating room.



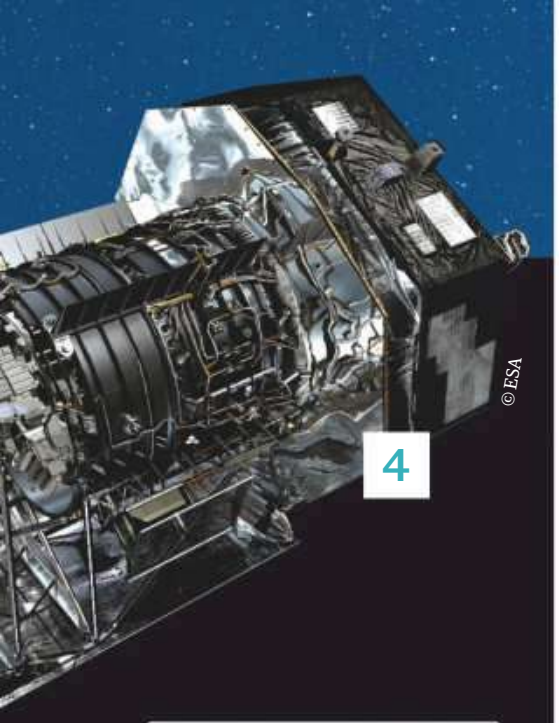


2 Giotto

This ESA mission was sent to study the famous Halley's Comet up close in 1986. The comet orbits the Sun roughly once every 76 years, and so it was a once-in-a-lifetime opportunity. One of the key findings was a higher proportion of so-called heavy water on Halley than is found in Earth's oceans. This made the case that comets like Halley were not the primary source of Earth's water as some astronomers had suggested.

3 Rosetta and Philae

In 2014 the ESA successfully landed the washing machine-sized Philae lander on Comet 67P. The orbiting Rosetta spacecraft found many examples of molecules never seen before on a comet, including the first undisputed discovery of glycine – the simplest amino acid. However, its findings also cemented the idea that the water content on comets is significantly different to that found on Earth.



4 Herschel Space Observatory

A telescope that saw in infrared, Herschel was used to peer more closely at Comet Hartley 2. It found that there was a good match between the proportion of heavy water present on the comet and in Earth's oceans. The comet is thought to have formed much further out in the Solar System than some of the other comets studied, and that may indicate that very long-period comets were the source of our water.

Right: The Herschel cryostat vacuum vessel being built at an ESTEC Test Centre in the Netherlands

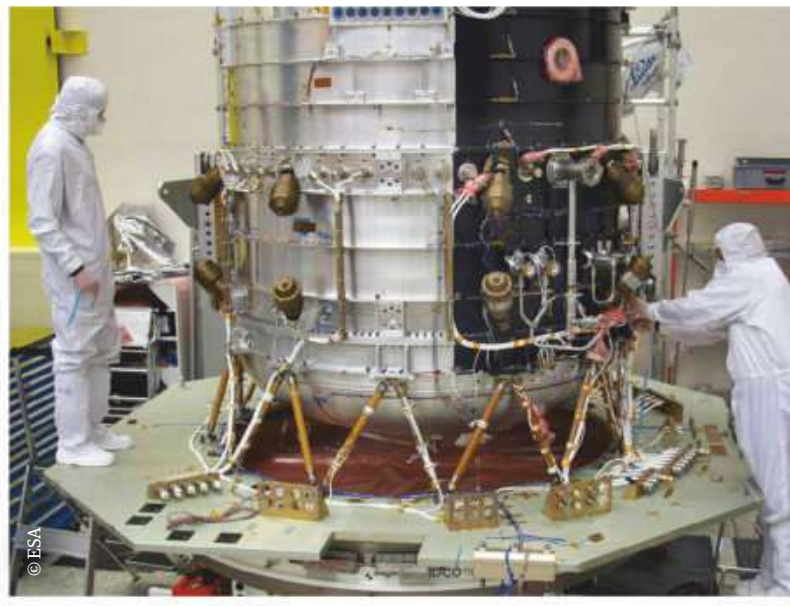
Below: An image of Comet Hale-Bopp with two distinct tails - the products of solar wind and flung grit

In a separate study, a team at the Institut de Chimie de Nice in France also mocked up artificial comets using different mixtures of ices. They cooled water, methanol and ammonia ices to -200 degrees Celsius (-328 degrees Fahrenheit) and then shone UV light onto the blend to simulate the glow of newborn stars. They then brought it up to room temperature to mock up the comet getting close to the Sun later in its life. They found several complex molecules had formed during the process – the most exciting of which was ribose, which helps form RNA. It must be stressed, however, that ribose is yet to be found on a real comet.

If amino acids and sugars are really created in this way in space, and many comets once rained down on our planet, comets could have delivered them to Earth. The exciting thing about that idea is that our planet wasn't the only place to get battered by comets in its infancy. The other planets, along with their bevy of moons, were also bombarded. Anywhere those molecules might have mixed with liquid water is an enthralling place to explore. That's particularly true for icy moons with liquid oceans.

"These moons have a big problem in that they orbit giant planets that might sweep up most of the impacts," says Duncan Forgan, an astrobiologist from the University of St Andrews, Scotland. "But all it takes is enough hits, and enough might not need to be big numbers." That puts Jupiter's moon Europa and Enceladus around Saturn top of the destination wish list for future robotic exploration.

But not all agree that comets are a big deal when it comes to kick-starting life. Lewis Dartnell from the University of Westminster believes amino acids were probably here on Earth all along, even before the comets hit. "If that chemistry is going on in space then it was almost certainly already going on in the primordial seas of planets like Earth and Mars," he says. Glycine, for example, could have been present in the cloud of gas and dust that collapsed to form the Sun and the planets. That way glycine would have become incorporated into Earth whether comets bombarded us or not. Radio astronomers have attempted to detect glycine in similar gas clouds elsewhere in our galaxy with mixed results. Some have claimed a discovery, but others have questioned their findings.



The picture is still blurry. It just goes to show that the origin of life on Earth is a complex story with many twists and turns. Slowly but surely, however, we are starting to piece together the tale of how our planet came to host living things. In doing so we might also get a better idea of the chances of finding other life forms out there among the stars. Because if comets did indeed make a significant contribution to Earth's complex chemistry, there could be new planets out there being showered with comets right now, setting the wheels in motion for a brand-new form of alien life to take hold.

Comets contain sugars such as ribose

Laboratory experiments suggest ribose may form naturally on comets. Ribose is a crucial part of RNA (ribonucleic acid), which is highly similar to DNA (deoxyribonucleic acid).

OUR UNIVERSE'S MISSING LINK

Our model of the cosmos needs revision, but not without astronomers first assembling the pieces of a new cosmological puzzle

Reported by Lee Cavendish

© Getty

Universe's missing link

Observation and theory make up the two pillars of scientific research. Without observations, there is just a theory with no substance, and without theory there is just a series of measurements with nothing to extrapolate from them. But what happens when one does not satisfy the other? Recent research about the expansion of the universe and the model that astronomers use to predict its history has caused tension between these two pillars. It appears as though recent measurements of galactic distances over a hundred million light years away and their respective recession speeds have contributed to a persistent discrepancy that keeps cropping up.

Measuring the distance to galaxies has been a relentless objective of astronomers since the beginning of the 20th century. Although many names can be attached to discovering the expansion of the universe – such as Vesto Slipher, Carl Wirtz, Knut Lundmark and Georges Lemaître – it was the work of an American astronomer called Edwin Hubble, the eponym of a law, a constant and a space telescope, who had the most profound effect on this area of research.

In the 1920s Hubble used a telescope at the Mount Wilson Observatory, California, to study the cosmos in unrivalled precision. By doing this he discovered that what astronomers thought were nebulae – clouds of gas and dust illuminated by internal stars – were actually other galaxies outside the Milky Way. He then went on to measure the distances to these galaxies by studying their internal Cepheid variable stars and inferring the distances using a luminosity-distance relationship.

Cepheids were first cited as distance markers in 1912 by another American astronomer, Henrietta Swan Leavitt, who noted that the regular luminosity fluctuation of variable stars can be mathematically manipulated to derive the distance between Earth and that star. This is one class of astrophysical object used to measure distances, commonly referred to as 'standard candles'. By studying Cepheids in distant galaxies and using measurements gathered by other astronomers, Hubble was able to obtain distance measurements for 46 galaxies and uncover something truly groundbreaking.

In 1929 Hubble announced that there is a proportional relationship between a galaxy's distance from Earth and its recession velocity. In other words, the greater the distance between Earth and the galaxy, the greater the speed at which the two are moving apart. This is now known as 'Hubble's law', and the accompanying constant of proportionality – known as the Hubble constant (H_0) – was predicted to be 500 kilometres (310 miles) per second (the speed) per megaparsec (distance in units favoured by astronomers). However, this was not correct at all, and actually implied that

Right: Standard candles are shining examples of astrophysical objects used to calculate cosmic distances

Below: The Hubble Space Telescope has been just as influential to astronomy and cosmology as its namesake

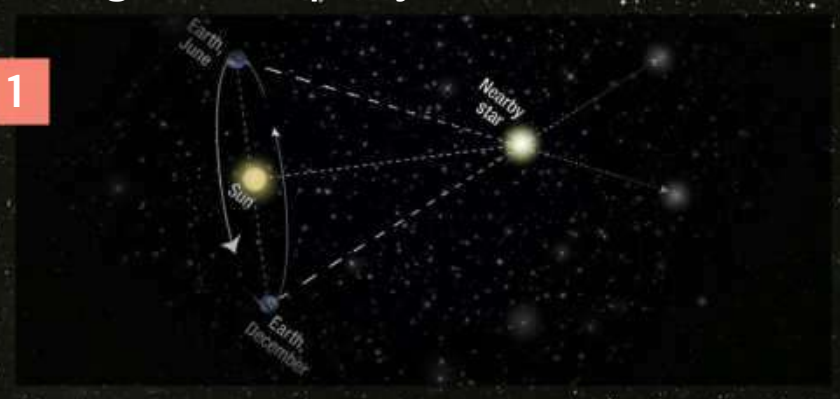
© Adrian Mann

HOW DO WE CALCULATE THE HUBBLE CONSTANT?

The problem causing the discrepancy could lie somewhere in these methods

1 Parallax

Parallax is an ancient method for measuring the distance to relatively nearby stars up to approximately 65 light years away using Earth-based measurements - or 326 light years if having used the ESA's Hipparcos mission. This method uses trigonometry to measure the displacement of a star's background, having observed it from the opposite side of the Sun. This method is commonly used as the first step on the 'cosmic distance ladder' which astronomers use to calibrate other results.



© NASA, ESA

© NASA, ESA, and the Hubble Heritage Team

2 Cepheids

Cepheids are unstable stars that are coming to the end of their lives. During this period of imbalance, there is a periodic pulsation to the star. From Earth this pulsation appears as a timely dimming and brightening. Astronomy changed when Henrietta Swan Leavitt discovered the periodic pulsating could mathematically infer the star's distance up to 20 million light years using what is now known as the 'period-luminosity relationship'.

3 Type Ia supernovae

Another standard candle that helped provide a more recent Hubble constant figure are Type Ia supernovae. These are not stars by definition, but are instead the explosive events that mark the end of a white dwarf star. Specifically one more than 1.44 times the mass of our Sun. The peak luminosity when they explode is consistent across the universe, and therefore astronomers can take the observed magnitude and use a similar distance-luminosity relationship equation to determine the distance to galaxies tens of millions of light years away.

© ESA

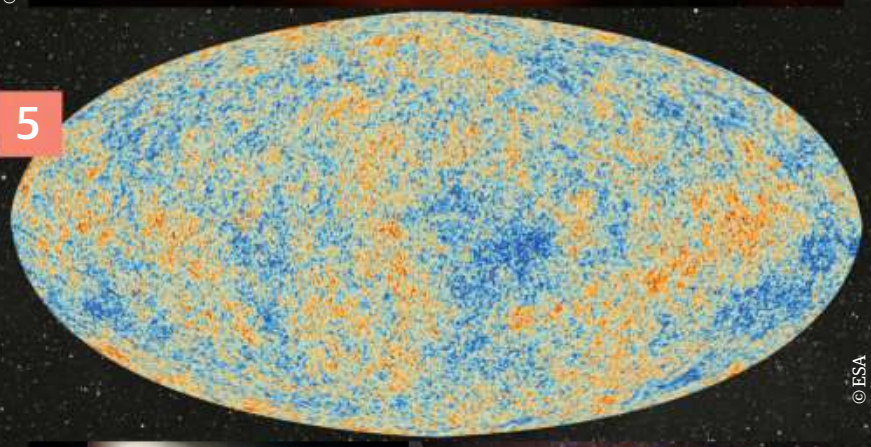
4 Redshift

This is the ultimate ruler when it comes to working out cosmic distances. In the past galactic redshifting revealed the distance to the farthest known galaxy from Earth, GN-z11, which is 13.4 billion light years away. This method requires spectroscopic data of a galaxy, then astronomers determine how far the emission or absorption lines for elements have shifted to the red end of the electromagnetic spectrum.

© NRAO

5 Cosmic microwave background

The CMB is leftover heat radiation from the Big Bang that can only be seen when observing the universe through microwave wavelengths. This provides visible and accessible information about what the universe was like over 13 billion years ago. In order to paint the best picture, astronomers have produced cosmological models that fit the CMB data. It just so happens that these models predict a different figure for H_0 than what is calculated using standard candles and megamaser geometry.



© ESA

© NRAO

6 Megamaser geometry

Masers are radio analogues for visible-light lasers, and can therefore be easily picked up by Earth-based observatories. By measuring a maser's centripetal acceleration and radial velocity, the Megamaser Cosmology Project then applies geometry to calculate the distance between Earth and the host galaxy. This is unique because it is independent of standard candles and the CMB, and therefore the results carry more weight and provide a new outlook on the discrepancy.

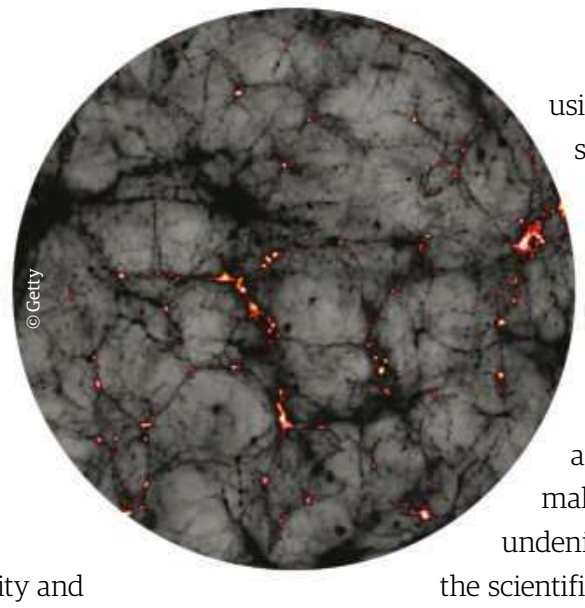
THE TELESCOPES THAT YIELDED THESE RESULTS

the universe was only 2 billion years old. At the same time geological records showed Earth was at least 3 billion years old, which certainly had people scratching their heads.

Over the years techniques have been refined, and other standard candles have been added to the astrophysical roster in order to come to a more believable figure. In 2019 Dr Adam Riess of the Space Telescope Science Institute (STScI), Johns Hopkins University in Baltimore and Nobel laureate of 2011 arrived at a figure of 74.03 kilometres (46 miles) per second per megaparsec using Cepheid stars, type Ia supernovae and the Hubble Space Telescope. This is the figure that will be commonly quoted when referring to the Hubble constant. This is arguably the most influential constant used within astrophysics and cosmology. It is based on undeniable evidence that the entire universe is expanding at an increasing rate at larger distances, with Earth being no geocentric exception to the rule. The universe is homogeneous and the Milky Way is travelling through the cosmos just like everything else.

The Hubble constant also means that there is a timeline to the universe. The cosmos must have originated from a single point of initial expansion, evolved over the last 13.8 billion years and will perhaps come to a crunching, freezing or ripping

"DARK ENERGY PERMEATES ALL OF SPACE AND CREATES A TENSION IN THE UNIVERSE THAT CAUSES THE EXPANSION OF THE UNIVERSE TO ACCELERATE" JIM BRAATZ


© Getty

end at some point. The discovery of Hubble's law and its constant had major implications for the Big Bang theory, dark energy and the current standard model of cosmology: Lambda Cold Dark Matter (LCDM) theory.

"[This theory] describes a universe that is governed by Einstein's theory of gravity and general relativity. The model says that the universe is made mostly of 'dark energy' and 'dark matter', neither of which we understand very well," explains Dr Jim Braatz, an astronomer at the US' National Radio Astronomy Observatory (NRAO) and lead of the Megamaser Cosmology Project, to **All About Space**. "Dark energy permeates all of space and creates a tension in the universe that causes the expansion of the universe to accelerate as it ages. Dark matter is a component of the universe that exerts gravity but does not shine in any sort of light. This type of matter – called baryonic – which makes up all the stars, gas, dust, planets and people, is a very small part of the universe according to this model, and most competing models too."

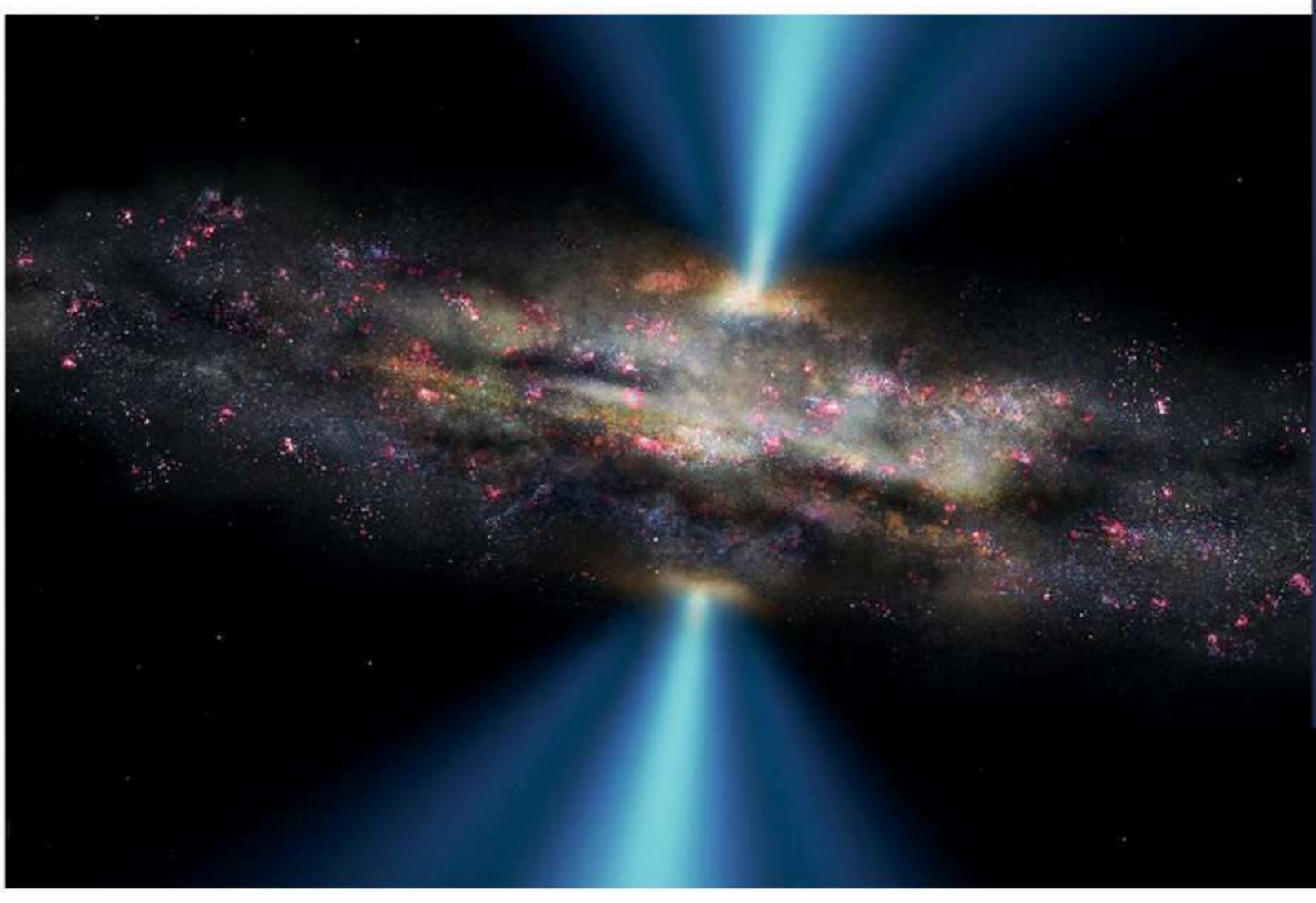
It has been no easy ride confining the number for H_0, and the figure has changed continuously over the years as astronomers attempt to measure cosmic distances and recession speeds using different methods. The scientific community needs to unanimously agree upon a figure, and that can only be done by arriving at the same figure – or having overlapping uncertainty percentages – using unrelated and unique techniques. This makes it hard to argue against the undeniable evidence, and is essentially the scientific process for anything. In this particular case the Hubble constant has also been inferred using data collected from relic radiation left over from the birth of the universe, which is known as the cosmic microwave background (CMB).

Scientists have developed models of the universe to fit the observations and measurements taken from the CMB by the European Space Agency's (ESA) Planck satellite. The figure they arrived at was 67.4 kilometres (41.9 miles) per second per megaparsec, with an uncertainty of less than a per cent. That the uncertainty bar doesn't overlap with the uncertainty bars derived from astrophysical techniques has since created a discrepancy.

The Megamaser Cosmology Project is an international effort to measure the Hubble constant using precise geometric distances. This outstanding team effort has derived a figure for the Hubble constant without using any standard candles or the CMB, but instead using radio telescopes in the US

Above: Theoretically a dark matter web permeates throughout the entire universe

Below: A single galaxy can potentially contain millions of supernovae, Cepheids, megamasers and other cosmic lighthouse signals used to calculate distances


© Yale University / OPAC

WHAT ARE THE POSSIBLE EXPLANATIONS?

Dark energy's early influence

Dark energy, which makes up about 70 per cent of our universe, could have provided an unexpected input of energy after the Big Bang which caused the universe to expand faster than predicted. This is called the 'early dark energy'.

A new subatomic particle

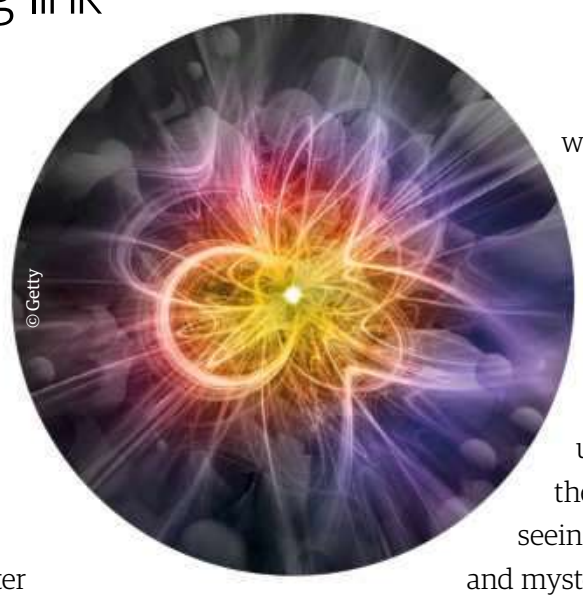
This could provide a new objective for the next generation of particle accelerators. The discrepancy could be explained by the existence of a subatomic particle that moves close to the speed of light, which when influencing the universe collectively is also referred to as 'dark radiation'.

Stronger dark matter interaction

Dark matter, which makes up approximately 25 per cent of our universe, could interact with ordinary matter, which makes up just five per cent, with more intensity than originally thought. The issue is that dark matter cannot be observed directly. It emits no light and only interacts with ordinary matter through the medium of gravity.

Waiting for a new theory

This is a complete mystery, and while astronomers stay determined to provide a figure for the Hubble constant with as little uncertainty as possible – the aim being less than one per cent – the same people could be coming up with new and groundbreaking theories that could bind the two observations.


© Getty

and Germany to identify water-bearing molecules in galactic centres.

"The centres of most galaxies have supermassive black holes. If there is sufficient dust and gas near these black holes, the material can form an accretion disc that feeds material to the black hole, and it can radiate profusely. Water vapour is a trace constituent of the accretion disc, and fortunately it can emit maser light at radio wavelengths. Maser, like 'laser', is an acronym. It stands for microwave amplification by stimulated emission of radiation," explains Dr Mark Reid, a senior radio astronomer at the Smithsonian Astrophysical Observatory, Massachusetts, to **All About Space**. "We see bright clumps of maser emissions from the water vapour and can measure Doppler shifts, positions and angular motions. Simplifying things a lot, if you measure a galaxy's speed and angular speed, you can get a distance.

"The technique used to measure the extremely small angular motions of the masers is called very-long-baseline interferometry (VLBI). This technique requires making measurements on a large number of baselines in order to reconstruct an image of what the radio sky would look like were we to have a telescope the size of Earth and could see radio waves," Reid continues.

In total the distances for six galaxies – UGC 3789, NGC 6264, NGC 6323, NGC 5765b, CGCG 074-064 and NGC 4258 – were measured, ranging between 168 million and 431 million light years from Earth. This research gave a figure of 73.9 kilometres (45.9 miles) per second per megaparsec as the Hubble constant, with an uncertainty of plus/minus three kilometres (1.86 miles) per second per megaparsec. This figure is therefore more consistent with the standard candle method.

"It is really essential that we get small uncertainties and unbiased measurements. Geometric methods can be particularly valuable because those methods and their uncertainties are entirely unrelated to those associated with standard candles," says Braatz. "Moreover, a distance measurement at large distances beyond about 150 million light years provides a direct measurement of H_0 in one step, rather than using the traditionally staged calibrations known as the 'distance ladder'.

"Our measurement of the Hubble constant is very close to other recent measurements, and is statistically very different from the predictions based on the CMB and the standard cosmological model. All indications are that the standard model needs revision."

So what does this mean for the standard model? "There is something in fundamental physics that is missing from the model, and we don't know what it is," says Braatz. "It may be related to our understanding of particle physics. For example, if some new type of particle played an important role in the growth history of the universe, it could show up as the type of discrepancy we are seeing. It may be an unknown and mysterious manner of interaction between different types of matter. It may be an exotic new form of energy."

"If real – and not just some subtle measurement issue – the H_0 discrepancy looks to be a fundamental clue to new physics," Reid explains. "It could be that the very early universe does not follow the favoured model, the LCDM theory, or that there is an extra type of neutrino or some other very basic lack of knowledge."

There are a number of possible reasons as to why this discrepancy is evident, and it is possible that there is a mysterious force at play that physicists are completely blind to. This would mean changing the standard model – which in the past a large number of astronomers believed was the solution to cosmology's greatest mysteries – to suit the observations. At the same time teams of astronomers are still improving their analysis techniques in order to improve their uncertainty.

But as the technological and engineering age advances, this means new telescopes and technologies are being taken advantage of for scientific benefit. For example, when Riess won his Nobel Prize in physics in 2011 along with Saul Perlmutter and Brian Schmidt, they had the help of recently introduced CCD imaging sensors. For the megamaser geometric method, Braatz believes that the Next Generation Very Large Array (ngVLA), a radio telescope array that could be up and running as early as 2028, could provide the improved sensitivity required to reduce the uncertainty when measuring the Hubble constant.

Whatever the eventual outcome, it is clear that there is a call for attention towards what can only be referred to as a cosmic conundrum. There needs to be more observations, less uncertainty and a theory that can account for this discrepancy in figures between astrophysical and CMB measurements. Could this mean trying to find a new particle? Could this mean re-evaluating our understanding of dark matter and dark energy? Or was there an unaccounted event in the universe's early evolution that could explain this?

> "IT IS REALLY ESSENTIAL THAT WE GET SMALL UNCERTAINTIES AND UNBIASED MEASUREMENTS. GEOMETRIC METHODS CAN BE PARTICULARLY VALUABLE" JIM BRAATZ

Above: **A new particle may need to come to light in order to explain this discrepancy**

Right: **VLBI utilises worldwide radio antennae which collaborate and form an Earth-sized radio telescope – albeit a very patchy one**

© NRAO

3 FREE DIGITAL BOOKS FOR EVERY READER!

MENSA HIGH IQ TEST

Welcome to the ultimate test of logic! Inside this book you will find 180 stimulating and challenging logic puzzles – from mathematical equations to riddles and number patterns – separated into nine tests. Each of these thought-provoking puzzles has been created by a team of leading puzzle-setters to help boost brain activity and improve concentration and memory while also providing hours of puzzling, brain-bending entertainment! If you are looking for an activity that can help you improve your cognitive powers while simultaneously keeping you entertained for hours at a time, then look no further. Get ready to put your mind to the test.

TEACH YOURSELF ASTROPHOTOGRAPHY

Astrophotography can seem very daunting at first, but it's one of the most rewarding hobbies once you learn the basics. The photographic possibilities that the night sky offers are incredibly vast, from landscape shots with the Milky Way behind them to photographing far-away planets and galaxies. Explore the differences between galaxies and nebulae, find out when to shoot the Moon and learn how to capture aurorae. Inside we've included jam-packed features, in-depth tutorials, interviews with professionals and creative projects. Whether you're a novice or seasoned space expert, **Teach Yourself Astrophotography** has something for you.

WORLD OF TOMORROW

Do you ever wish you had a crystal ball so you could take a peek at the distant future? Now you can with this new edition of **How It Works World of Tomorrow**. While it's no magical artefact, it does offer a glimpse of future developments in transport, medicine, entertainment and space travel based on the innovations taking place in the present day. Learn more about how humans will live, interact and better the planet we live on – as well as other planets – in the future. Whether you want to know if we'll leave our roads and pavements behind or whether we'll ever be able to take holidays to other planets, you will find the answers in this book – no crystal ball required.

DOWNLOAD YOURS NOW AT: SURVEYMONKEY.CO.UK/R/09AAS

ASK Space

Our experts answer your questions

ASTROPHYSICS

What happens to gas as it falls into a black hole?

One of the biggest misconceptions about black holes is that they indiscriminately suck up everything around them. A black hole is incredibly small, and so gas on a collision course with a black hole would need to have incredibly precise aim in order to directly hit the black hole. Instead gas starts orbiting around the black hole, eventually creating what we call an 'accretion disc'. As gas funnels closer and closer to the black hole, the gravitational potential energy that the gas had is released. This then dissipates in the form of heat, radiation, massive outflows and sometimes jets of particles moving at close to the speed of light. One question we want to answer is: where does all of the X-ray emission come from around a black hole?

High-energy X-rays are ubiquitous in accreting black holes, and yet we don't understand the mechanism that produces them. The idea is that some extremely hot region surrounds the black hole, referred to as the 'corona', causing some photons to get boosted to X-ray energies. How the corona is formed, and how it remains hot for so long, is still a mystery – although we recently witnessed, in real time, the destruction and reformation of a black hole corona.

Astronomers also have evidence to believe the power output from supermassive black holes can affect how their host galaxy evolves. Not only are black holes these exotic, mysterious objects where the laws of physics break down, they are also incredibly important for understanding why our universe looks the way it does.

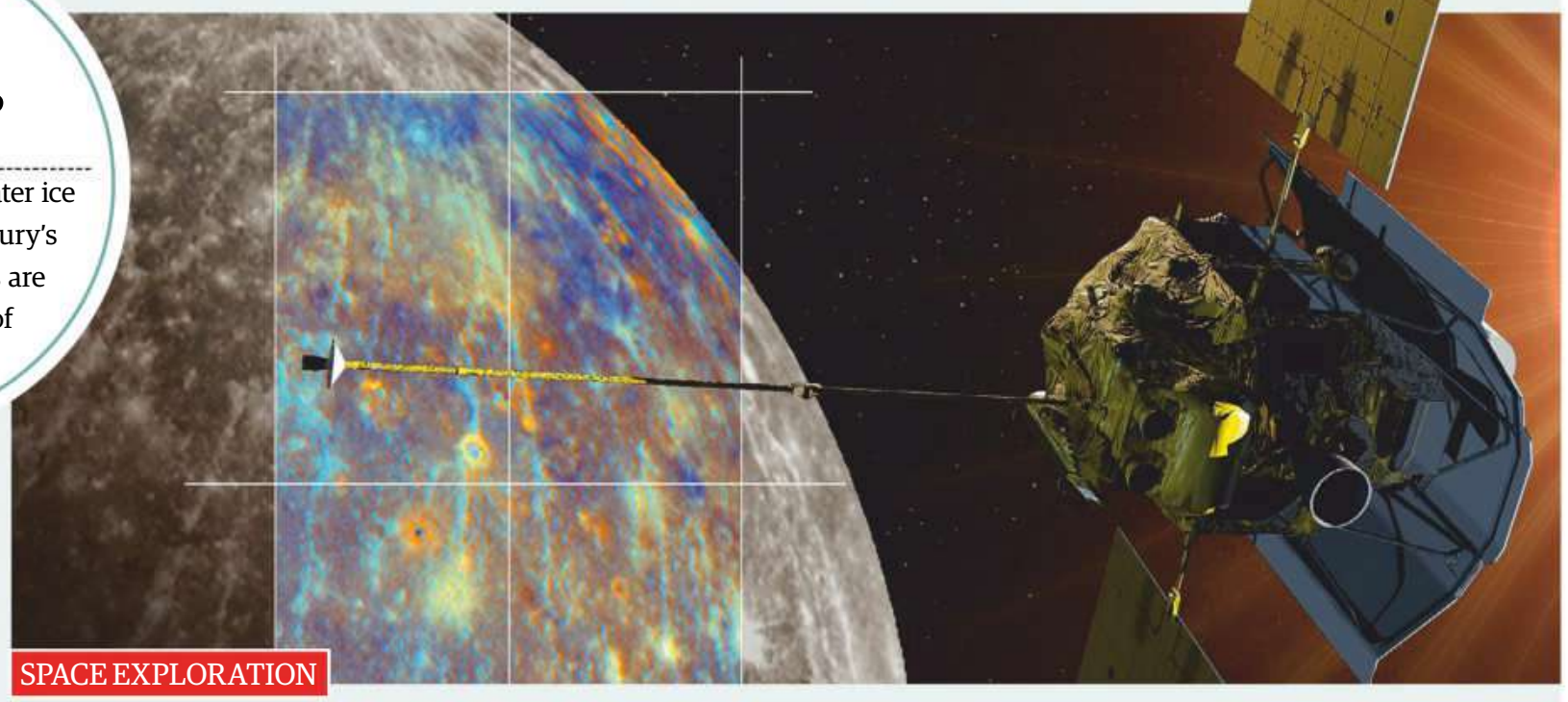
Dr Erin Kara is an assistant professor at the Massachusetts Institute of Technology

Although astronomers can't directly observe black holes, they can observe the accretion discs around them

© NASA/JPL-Caltech

Did you know?

MESSENGER discovered water ice in the craters around Mercury's north pole. These regions are shaded from the heat of the Sun.



© NASA

Above: MESSENGER's mission ended on 30 April 2015 when the spacecraft plunged into the planet's surface

SPACE EXPLORATION

What were the best results obtained from the MESSENGER spacecraft's trip to Mercury?

The big surprise was that Mercury's powder-rocky material, the part we can see on the surface, had been predicted for many decades to be deficient in elements and compounds that are easily removed at high temperatures.

The one thing we knew before any spacecraft ever went to Mercury is that it has got a very high fraction of metallic iron. The question is, how do you make a planet that is mostly iron, but is otherwise produced by the same properties that produced Earth, Mars and Venus? The prediction was that Mercury would be very deficient in elements that are easily removed at high temperatures, just like Earth's Moon. These are what the chemists like to call 'volatile elements'.

Once we started measuring what's at Mercury's surface, we realised that wasn't the case. Mercury is high in sulphur. It has ten times the abundance of sulphur of the surface of Earth. Mercury has high abundances of sodium, potassium, alkaline metals that are easily removed at high temperatures and chlorine. Mercury has a higher chlorine abundance relative to several elements on Earth.

© NASA

Sean Solomon was principal investigator of NASA's MESSENGER

© Paul Scholar/ANSMET

Right: Frequent voyages are made to the Antarctic in order to build an inventory of meteorites

SOLAR SYSTEM

Why is Antarctica popular for finding meteorites?

Meteorites are scientifically valuable because they represent samples of a variety of asteroids and planets, like the Moon and Mars. Studying them in our laboratories has led to important insights into the origin and evolution of our Solar System and planets. At present, Antarctic meteorites dominate the inventory of the world's known meteorites, and these samples have provided us with access to new types of planetary and asteroidal materials. Both hot and cold desert regions of the world are some of the best hunting grounds for meteorites. This is not because there are any more meteorites that fall there than any other place on Earth, but because the conditions in these places are such that meteorites are easier to find. Antarctica in particular has proven to be one of the best places in the world for finding meteorites. This is because the geological and environmental conditions on some ice sheets in Antarctica serve to concentrate and preserve the meteorites that have fallen there.

© Sue Selkirk/ASU

Meenakshi Wadhwa is a director and professor at the School of Earth and Space Exploration at Arizona State University

ASK Space

Our experts answer your questions

ASTROPHYSICS

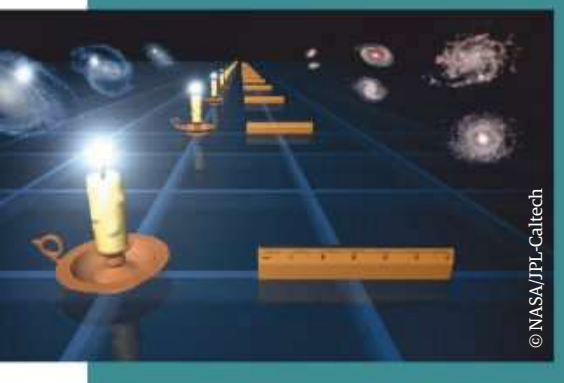
How do we determine the distance to an object?

For nearby objects, astronomers use parallax, a visual effect produced by a shift in the relative position of the observer with respect to the object.

For objects further away, astronomers make use of 'standard candles'. These are objects with known brightness, such as Type Ia supernovae, which have normalisable peak brightnesses. Astronomers also use variable stars that pulsate with a period that is directly related to their brightness. By measuring how bright these objects appear to be, you can work out how far away they are.

For objects outside our galaxy to the most distant objects in the universe, astronomers use spectroscopy, which splits the light from an object into its various wavelengths to identify features such as emission or absorption lines. Due to the expansion of the universe, objects appear to be moving away from us at velocities proportional to their distance. The further away an object is from us, the faster it appears to be moving. By measuring the 'redshift' of a spectral line, astronomers can accurately determine the distance of the object.

Dr Kerry Paterson is a postdoctoral associate at Northwestern University, Illinois



© NASA/JPL-Caltech

Left: Astronomers use standard candles as a way to determine the distance to an object from its apparent magnitude

Right: The MAGIC telescopes are based at the Roque de los Muchachos Observatory in La Palma, Canary Islands, Spain

© Tobias Roetsch

SOLAR SYSTEM

How can spectroscopy reveal so much about asteroids and comets?

Spectroscopy is the process where we point a telescope at an object in space and pass the light from that object through an instrument, which in turn, spreads the light out. Light is arranged by wavelength into a pattern called a spectrum. We collect spectra with detectors that translate this into data that we can then go on to analyse.

It is known that asteroids are made primarily of rock, while comets are a mix of ices and rock. This is why comets are commonly referred to as 'dirty snowballs'. Those rocks and ices absorb and emit light at specific wavelengths, making a spectral fingerprint. By studying the spectrum of an asteroid or comet, we can identify the fingerprints associated with different types of rock and ices. We then know what the asteroid or comet is made out of without having to collect a sample. The composition of asteroids and comets can tell us about how and where they formed, and how they've changed over the age of the Solar System. We can use that information to study one particular small body in detail or how populations of small bodies are distributed throughout the Solar System.

Dr Zoe Landsman is chief scientist at the Center for Lunar and Asteroid Surface Science

Left: Spectroscopy can reveal a lot about the history of an asteroid or comet

ASTRONOMY

What is unique about the MAGIC telescopes?

© Giovanni Ceribella/ MAGIC Collaboration

The two Major Atmospheric Gamma Imaging Cherenkov Telescopes, or MAGIC, look at the most energetic photons reaching Earth. This corresponds to very high-energy gamma rays. The MAGIC collaboration was formally formed in 1998, and scientific observations started in 2004.

Even before that MAGIC was already investing in front-edge technologies to reach its goals, which is being sensitive to the lowest possible energies and moving the telescopes as fast as possible to catch transient events. What is unique about the MAGIC telescopes is that there is a continuous effort to make them fast and sensitive.

Lowering the accessible energy actually allows us to close the gap with spaceborne instruments searching for gamma rays. Similarly, the speed at which the telescopes need to move is defined by the duration of the transient phenomena to follow.

The telescopes are able to point anywhere in the visible sky within a few tens of seconds in order to catch very high-energy emissions from gamma-ray bursts (GRB) – extremely quick, energetic events. These unique characteristics led to the detection of GRB 190114C in January 2019, revealing for the first time an emission of photons reaching teraelectronvolt (TeV) energies from a GRB.

Dr Oscar Blanch-Bigas is an astrophysicist at the Institute for High Energy Physics (IFAE) at the Universitat Autònoma de Barcelona, Spain

ASTROPHYSICS

How does quantum information science affect gravity?

Astronomy is concerned with observing the heavens with increasing accuracy and then attempting to explain those observations. Quantum information science is currently focused on increased computation power, improved sensing and expanding our understanding of communication. All three of these areas intersect with astronomy broadly and gravitation specifically.

Quantum computing cannot yet directly provide numerical insights due to engineering challenges imposed by quantum noise. The hurdles that quantum noise presents highlight the sensitivity of quantum systems. This sensitivity can be exploited to make improved measurements in what's becoming known as 'quantum sensing'. High-precision astronomical measurements were on display in 2016 when the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced the first detection of gravitational waves. The precise spectroscopy of LIGO is aided by nearly every advance in metrology, including quantum sensing and related techniques.

Finally, nowhere is gravity more front and centre in astronomy than in the discussion of black holes. Here, deep connections between black hole physics and quantum information theory are exposed when considering quantum phenomena across the event horizon. The event horizon is the boundary past which nothing, even light, can escape the pull of the black hole. Information scrambling within black holes is studied using tools and techniques from quantum information science.

In summary, quantum information science has a beautiful overlap, both technologically and intellectually, with gravity that is poised to expand going forward on multiple fronts.

Dr James Daniel Whitfield is assistant professor of physics at Dartmouth College, New Hampshire

Did you know?

LIGO's arms are long enough – four kilometres (2.5 miles) – that the curvature of Earth was a factor in their construction.

Below: Quantum information science could hold the answers to understanding the true nature of black holes

© GETTY/SPL/Mark Garlick

GET INTO STARGAZING

The dark winter nights are approaching and provide the perfect opportunity to head outside to begin your new hobby

A common astronomy myth is that you need a telescope to be an astronomer. This is something that beginners to astronomy often hear when they're asking for advice on breaking into the hobby. It's true that a telescope can show you much more than the naked eye, or even a pair of binoculars, but the truth is, you don't really need a telescope to enjoy the night sky. What's even better is that getting involved in astronomy is absolutely free.

A beginner will often be advised to simply use their eyes to familiarise themselves with the night sky – most likely with the aid of a star map or a planisphere. In general, even if you're looking to buy a telescope at a later date, learning your way around is essential. Of course, if you're happy to use the bare minimum of tools available to you, then you'll be pleased to know that there's plenty you can see with the unaided eye.

Before you head outside there are a variety of things you should be aware of to get the most out of stargazing. First, you should allow your eyes to adapt to the dark to observe the fainter targets, and second, you should ensure that you've chosen the darkest site possible. Any light pollution is sure to make taking in the night sky difficult. While the Moon is one of the best targets for naked-eye and binocular-wielding astronomers, it is also a source of light pollution, and must be at its new phase or a slim crescent to cause minimum interference.

Finding yourself under untouched skies is a breathtaking experience, and you'll be amazed what you can see with the unaided eye. Star clusters, such as the Pleiades, are easily detectable, as is the star-forming region known as the Orion Nebula. The dusty path of the Milky Way is easily seen from a dark location. A cheap star guide or planisphere will help you to find these targets, but given that they are so readily visible, you're likely to find that you'll see them straight away. Astronomy really doesn't come at a cost at this stage.

It's not until you decide to get some magnification in your hands that money gets involved, but it doesn't have to be this way. Provided you choose wisely, your first pair of binoculars, or indeed your first telescope, can last you for years, and could even serve as a trusty backup to a later purchase.

"BEFORE YOU HEAD OUTSIDE THERE ARE A VARIETY OF THINGS YOU SHOULD BE AWARE OF TO GET THE MOST OUT OF STARGAZING"

Right: Even a basic telescope can allow you to get better views of the Moon and planets

All images ©Getty

FREE
DIGITAL POSTER
TOP 24 TARGETS FOR BEGINNERS

DOWNLOAD YOURS NOW AT:
TINYURL.COM/YYVKUWUW

JARGON BUSTER

Right ascension (RA)

Right ascension is to the sky what longitude is to the surface of Earth, corresponding to east and west directions. It's measured in hours, minutes and seconds since as Earth rotates we see different parts of the sky through the night.

Declination (Dec)

This tells you how high your object will rise in the sky. Like Earth's latitude, declination measures north and south. Its units are degrees, arcminutes and arcseconds. There are 60 arcminutes in a degree and 60 arcseconds in an arcminute.

Bortle scale

The Bortle scale measures the brightness of a night-sky location, quantifying the observability of an astronomical object and the interference caused by light pollution. Scale 1 represents excellent dark skies.

Sky quality meter

A sky quality meter device measures the luminance of the night sky at your location. Measurements of 21.75 magnitudes per square arcsecond or above represent excellent night skies – a great time to stargaze!

MEASURING THE SKIES

Forget about sky charts and smartphone apps – you can get a good idea of the distance between objects with nothing but your bare hands

1 degree

Hold out your index finger and you can measure the distance and apparent size of an object equivalent to one degree. The full Moon is 0.5 degrees.

5 degrees

By stretching out your arm and holding up three fingers, you are able to measure a distance between objects and an object's size equal to five degrees.

10 degrees

Your fist measures about ten degrees. If you can stretch out your arm and fit your fist between Jupiter and the Moon, then the pair are ten degrees apart.

20 degrees

By holding out your arm in front of you and spreading out your fingers, you are able to measure a distance of approximately 20 degrees across the night sky.

ALL ABOUT MAGNITUDES

An object's magnitude tells you how bright an object is as it appears from Earth. In astronomy magnitudes are represented on a numbered scale. Quite confusingly, the lower the number, the brighter the object. For instance, an object of -1 magnitude is brighter than one with a magnitude of +2.

THE NAKED-EYE ASTRONOMER

There are many night-sky wonders to behold – and you can see them with just your eyes alone

In theory your eyes can see down to a faint magnitude +6.0 under outstanding night-sky conditions - and, of course, with very good eyesight. That means that it's possible for you to see at least 9,000 stars all at once. When you're under the darkest of skies, it isn't just stars that will become obvious to you - there are galaxies, planets and star clusters making themselves known if you know where to look. While using a telescope or a pair of binoculars as well as observing filters will enhance your experience, knowing that you can see for thousands of light years is very rewarding.

We've already established that you need to let your eyes adapt to the dark and that you should avoid light pollution and cloudy skies, but there are other measures you should take to get the best out of your naked-eye astronomy experience. You should avoid alcohol and nicotine since they both depress the dark-adaption response of the eye.

The best time to get involved in observing is near the time of the new Moon so that you're not battling light pollution in order to seek out night-sky treasures. You should also aim to choose an area that has a good horizon and is devoid of obstructions such as houses, trees, mountains and hills.

No doubt that under the best skies you can get to, you'll most likely want to see as much as your eyes and conditions allow. Remember that you're likely to see planets and stars much more easily than galaxies and nebulae, even if they have the same magnitude. This is because these extended objects are much more diffuse than Solar System objects, which appear as concentrated points of light.

As the seasons wheel from one to the next, you'll find that the constellations will start to become familiar. During the evenings of winter, spring, summer and autumn, you might find the constellations and asterisms of Orion, the Big Dipper, the Summer Triangle and the Great Square of Pegasus with ease. You can use these familiar areas as signposts to find your way around the night sky.

TOP THREE NAKED-EYE TARGETS

Source: Wikipedia commons
© Rawastrodata

© NASA

Source: Wikipedia commons
© Adam Evans

Orion Nebula (M42)

Right ascension: 05h 35m 17s

Declination: -05° 23' 28"

Best seen: Winter

Constellation: Orion

Magnitude: +4.0

Glancing below the three stars of Orion's belt, you should be able to make out the Orion Nebula as a smudge in a dark, light-pollution free sky. The Great Nebula in Orion is a huge cloud of gas that is forming new stars about 1,344 light years away from our Solar System and is also visible from suburban areas.

The Pleiades (M45)

Right ascension: 03h 47m 24s

Declination: +24° 07' 00"

Best seen: Winter

Constellation: Taurus

Magnitude: +1.6

You can't miss the Pleiades star cluster during the nights of winter and spring. You should be able to see six or seven stars in a formation that's akin to a miniature version of the Plough, or Big Dipper, when seen with the naked eye. This open star cluster is visible even with light pollution.

Andromeda Galaxy (M31)

Right ascension: 00h 42m 44s

Declination: +41° 16' 09"

Best seen: Autumn

Constellation: Andromeda

Magnitude: +3.5

At a distance of 2.5 million light years away, the Andromeda Galaxy, also known as Messier 31, is the furthest object we can see with the unaided eye. You need a dark site to be able to see this spiral galaxy as a faint smudge in dark and moonless night skies in the constellation of Andromeda.

DARK-SKY DESTINATIONS

Go to the world's best night skies for a stargazing experience like no other

1 Natural Bridges National Monument

Bortle sky class: 1 to 3

Sky quality meter reading: 21.75 or above

Location: Utah, US

2 Chaco Culture National Historical Park

Bortle sky class: 1 to 3

Sky quality meter reading: 21.75 or above

Location: New Mexico, US

6 Galloway Forest Park

Bortle sky class: 1 to 3

Sky quality meter reading: 21.75 or above

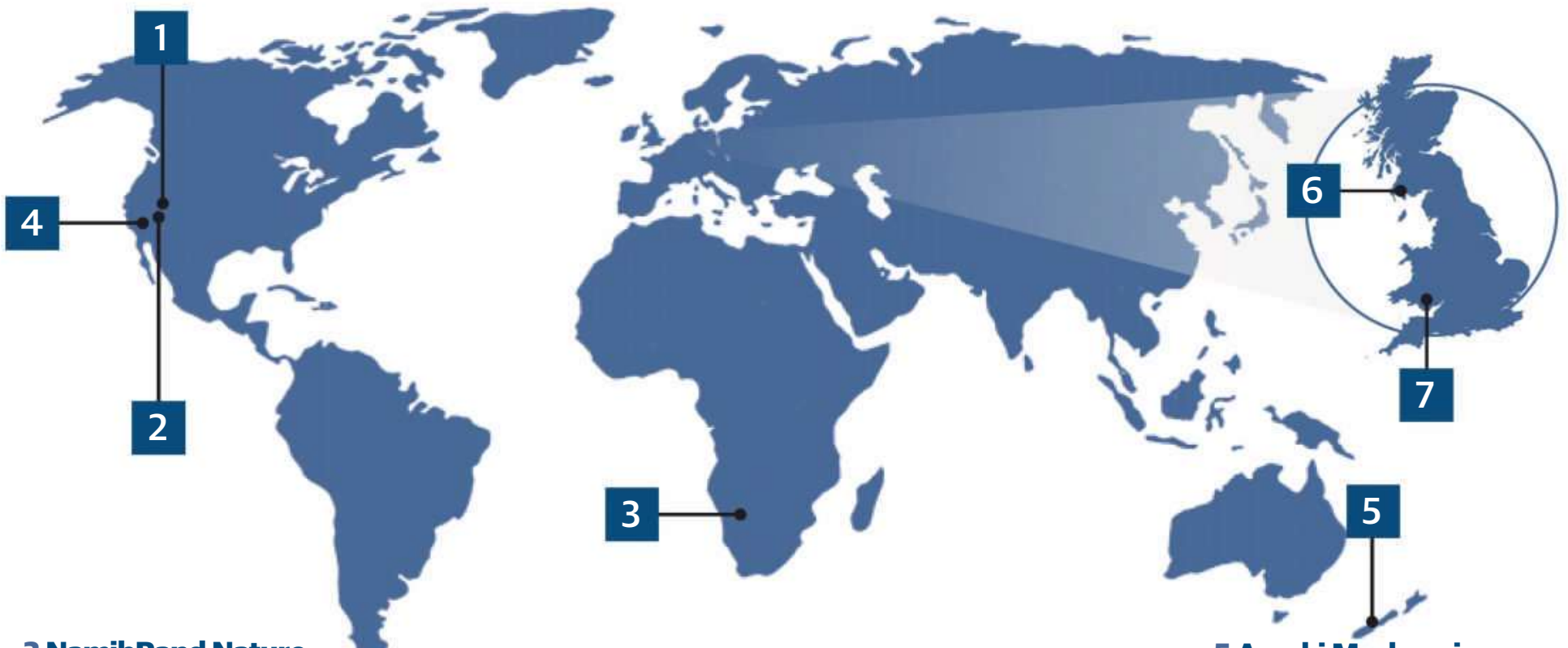
Location: Dumfries and Galloway, Scotland

7 Brecon Beacons National Park

Bortle sky class: 3 to 5

Sky quality meter reading: 21.00 or above

Location: Brecon, Wales



3 NamibRand Nature Reserve

Bortle sky class: 1 to 3

Sky quality meter reading: 21.75 or above

Location: Namibia, Africa

4 Death Valley National Park

Bortle sky class: 1 to 3

Sky quality meter reading: 21.75 or above

Location: California and Nevada, US

5 Aoraki Mackenzie International Dark Sky Reserve

Bortle sky class: 1 to 3

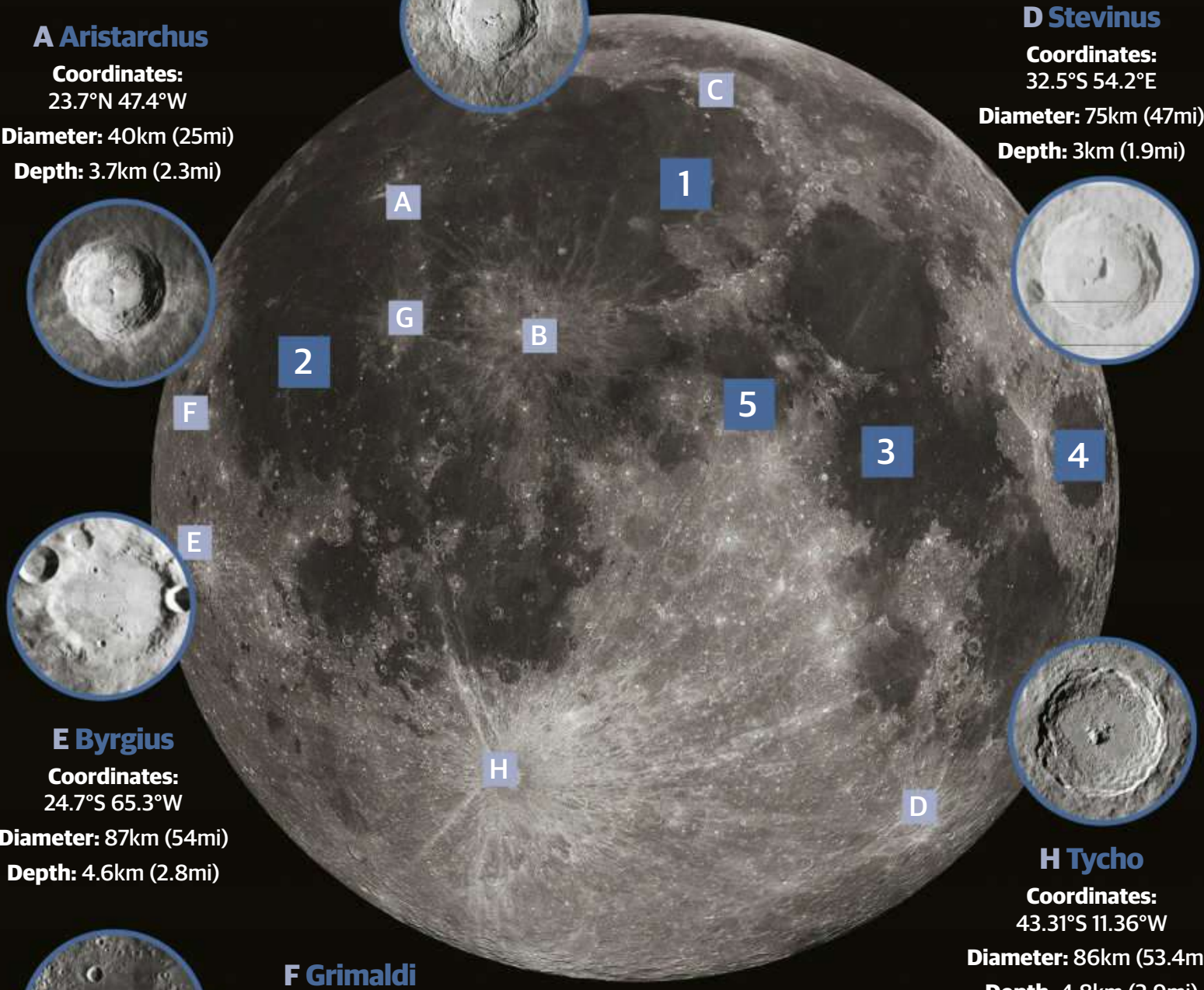
Sky quality meter reading: 21.75 or above

Location: South Island, New Zealand

© Getty

THE MOON
YOUR NUMBER ONE TARGET

All of these sights can be seen with the naked eye



KEY

Sea Craters

1 Mare Imbrium (Sea of Showers)

Coordinates: 32.8°N 15.6°W

Diameter: 1,146km (712mi)

A large circular sea, Mare Imbrium is immediately visible to the northeast of the great sea Oceanus Procellarum. Given its size, it can be picked out quite easily with the naked eye.

2 Oceanus Procellarum (Ocean of Storms)

Coordinates: 18.4°N 57.4°W

Diameter: 2,592km (1,611mi)

Not too tricky to spot with the naked eye, Oceanus Procellarum is best viewed when the Moon is full or when the Moon makes its morning appearance in the waning or last quarter phase.

3 Mare Tranquillitatis (Sea of Tranquillity)

Coordinates: 8.5°N 31.4°E

Diameter: 876km (544mi)

The sea where Neil Armstrong made the first-ever human footprint on the Moon. Visible during the full, first quarter, waxing gibbous and also the waning phase.

4 Mare Crisium (Sea of Crises)

Coordinates: 17.0°N 59.1°E

Diameter: 556km (345mi)

Fairly easy to pick out with the unaided eye, Mare Crisium is oval shaped and located to the east of Mare Tranquillitatis. It's visible to us on Earth during the first quarter, full and waxing phases of the Moon.

5 Mare Vaporum (Sea of Vapours)

Coordinates: 13.3°N 3.6°E

Diameter: 242km (150mi)

Close to Mare Serenitatis, this sea's dark appearance makes it easily detectable with the naked eye. It can be found close to the Moon's centre.

A Aristarchus

Coordinates: 23.7°N 47.4°W

Diameter: 40km (25mi)

Depth: 3.7km (2.3mi)

B Copernicus

Coordinates: 9.62°N 20.08°W

Diameter: 93km (58mi)

Depth: 3.8km (2.4mi)

C Plato

Coordinates: 51.6°N 9.3°W

Diameter: 101km (63mi)

Depth: 1.4km (0.86mi)

D Stevinus

Coordinates: 32.5°S 54.2°E

Diameter: 75km (47mi)

Depth: 3km (1.9mi)

E Byrgius

Coordinates: 24.7°S 65.3°W

Diameter: 87km (54mi)

Depth: 4.6km (2.8mi)

F Grimaldi

Coordinates: 5.2°S 68.6°W

Diameter: 173km (107mi)

Depth: 2.7km (1.7mi)

G Kepler

Coordinates: 8.1°N 38.0°W

Diameter: 32km (20mi)

Depth: 2.6km (1.6mi)

H Tycho

Coordinates: 43.31°S 11.36°W

Diameter: 86km (53.4mi)

Depth: 4.8km (2.9mi)

All moon images © NASA

PHASES OF THE MOON

Waxing crescent
In the late afternoon and just after dusk, the Moon begins its visible phases as a crescent.

First quarter
Around half the Moon can be seen, appearing in the late afternoon and early evening.

Waxing gibbous
Here the Moon can be seen to have a hunched back, with over 50 per cent of its surface visible.

Full Moon
The disc is completely illuminated and makes its grand appearance from sunset to sunrise.

Waning gibbous
Stepping back into the darkness, this waning phase is visible into the early morning.

Last quarter
You'd have to stay up late into the night and into the morning to catch the last quarter.

Waning crescent
The Moon's last visible phase can be caught in the pre-dawn and bright early morning sky.

©Alamy

MAGNIFYING YOUR EXPERIENCE

A pair of binoculars or a telescope can bring out the very best features of the night sky

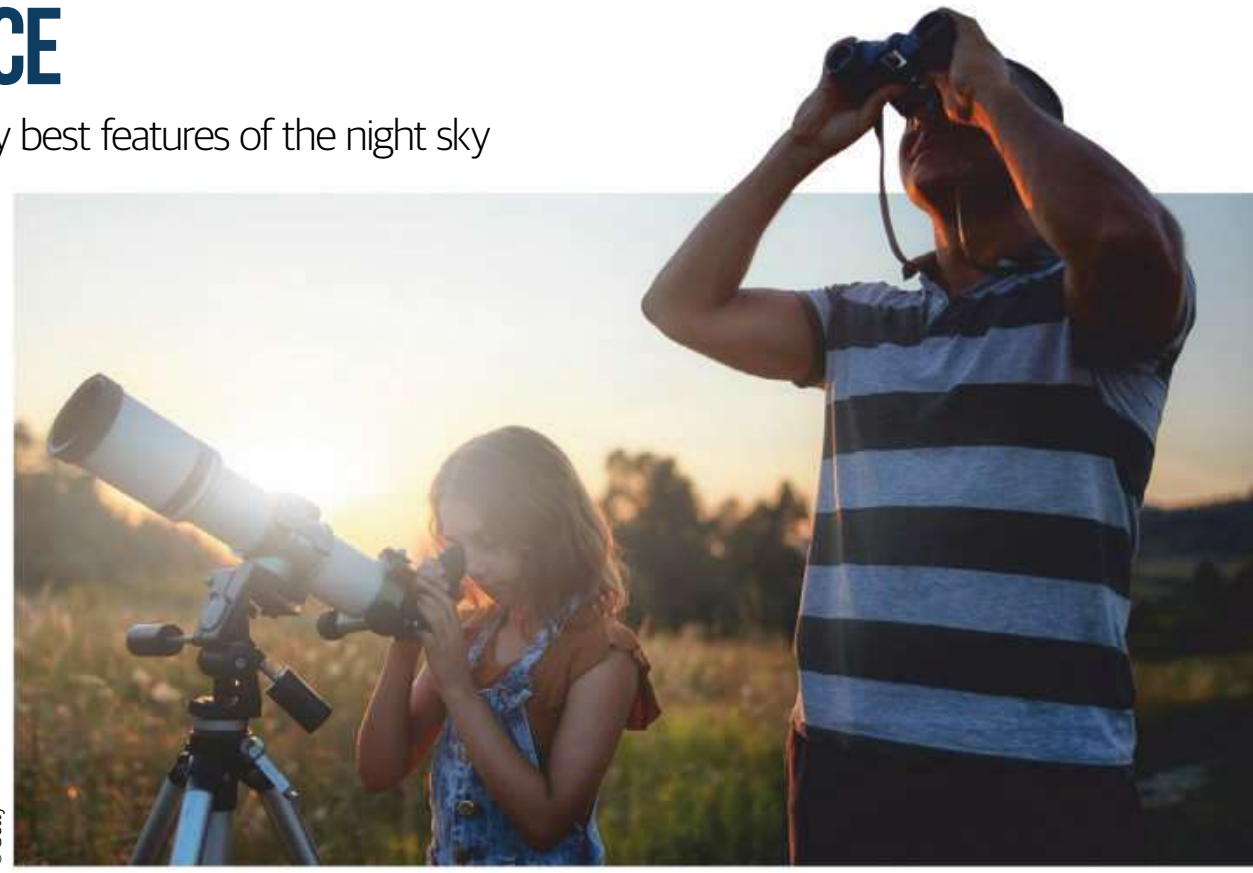
Naked-eye astronomy is a rewarding experience, but to really see as far into the universe as possible, you need an optical aid. Binoculars are always good to begin with, and just being in possession of a pair of 10x50s immediately opens up the opportunity to grab sights of night-sky targets that your eyes can't make out alone. Not only that, but simply increasing the magnification can provide even better views of objects that you can already see with the naked eye.

You should still give your eyes time to adapt to the darkness. Given that targets will be more difficult to find and that they can't be seen as well with the naked eye, you should make good use of a night-sky guide or planisphere and use a red torch to read it to preserve your night vision.

On your first night, you shouldn't expect too much. You are likely to see galaxies and nebulae that resemble faint, fuzzy patches of light. Planets, on the other hand, can appear marginally better, and the greater your magnification, the more impressive your view of our Solar System will be.

All's not lost with getting the best out of observing fainter targets though. With the help of averted gazing, which involves looking at an object using your peripheral vision, a faint object seen through your telescope or binoculars will appear brighter, since the rod cells around the outside of your eye are much more sensitive to the dim light of an object.

Right: Astronomy is a great family activity as well as one you can embark on alone – or with like-minded astronomers as part of a society



© Getty

To get the best views, you should take care of where you place your telescope. A stable surface is essential. Before you head outside you should also have an idea of what you wish to observe. Once you're outside and ready to gaze at the wonders of the night sky, experimenting with the magnification of your telescope by changing eyepieces will provide you with different and more impressive views of your chosen targets.

"INCREASING THE MAGNIFICATION CAN PROVIDE EVEN BETTER VIEWS OF OBJECTS"

HOW TO STAR HOP

1 Go old school

The simple solution to finding a celestial object is to use 'GoTo' systems on a modern telescope. These orientate a telescope to a desired object with almost no user input. If not available, you must star hop: navigate through the night sky by jumping from one known celestial object to another. When using small, mobile scopes, this is often an essential skill.

2 Get chart friendly

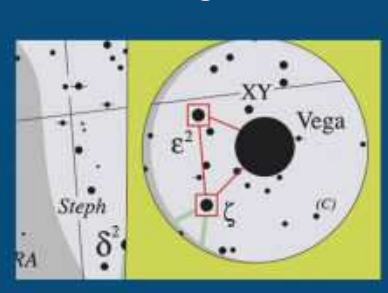
To star hop there are a few things you need, and a star chart is a must-have – one that shows stars and other objects clearly. While you can probably see the chart's contents clearly when you buy it in the middle of the day, at night it will be – hopefully – pitch black at your stargazing spot. To see properly, make sure you partner the chart with a red-light torch.

3 Find your field

Determine the field of view (FOV) of your binoculars or telescope. This is written on binoculars, but not telescopes. To find it on telescopes divide the apparent FOV of the eyepiece, usually specified by the manufacturer, by the telescope's magnification. The finderscope has a larger FOV than the main scope, so start with your lowest magnification eyepiece.

4 Try templating

It's useful to have an FOV template too. This can be achieved with a few square centimetres of clear plastic, a drawing compass and a felt-tip pen. Find a star on the chart, centre the view finder on it, check the stars on the edge of the FOV and then draw a circle on the plastic with the compass point on the star in the middle of the FOV. This will encircle the stars on the edge of the field.



5 Star hop to target

Find a bright or easily recognisable star in the middle of your scope's FOV. Note the stars at the edge of the field in the direction your target object lies in. Move the scope so the stars that were at the edge of the FOV on one side are now on the other. Repeat to find more chart-recognisable stars. You can jump across the night sky using the chart as a map to follow your target.

© Ed Crooks

STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

In this issue...

68 **What's in the sky?**
As we enter the point of darkening skies, see what autumn has to offer

72 **Month's planets**
Dusk to dawn belongs to the ice giants this month, as Jupiter also offers a spectacular view

74 **Moon tour**
Get the best views of the most dramatic cliff on the face of the Moon, Rupes Recta

75 **Naked eye & binocular targets**
Find stunning spiral galaxies that lie many light years away

76 **Deep sky challenge**
A ghostly nebula and a rose-shaped star cluster are among your observing challenges

78 **The Northern Hemisphere**
Myriad targets are on show throughout the cooler

80 **Telescope review**
Is the Celestron NexStar 127 SLT the right telescope for you?

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

What's in the sky?

11 SEP
Asteroid 19 Fortuna is well placed for observation in Pisces at magnitude +9.4

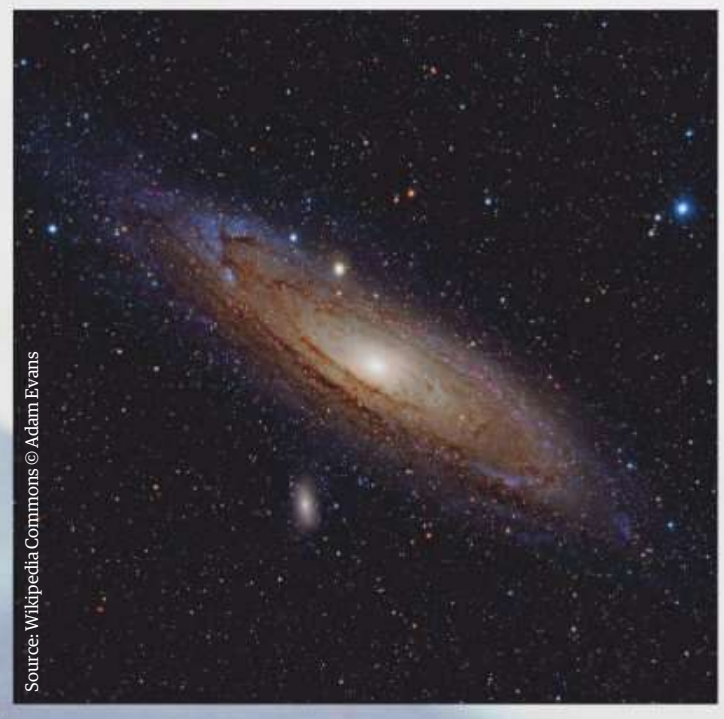
Source: Wikipedia Commons © Kevin Heider

11 SEP
Neptune is at opposition and well placed for observation in Aquarius

19 SEP
Mercury reaches its highest point in the evening sky, shining brightly at 0.0

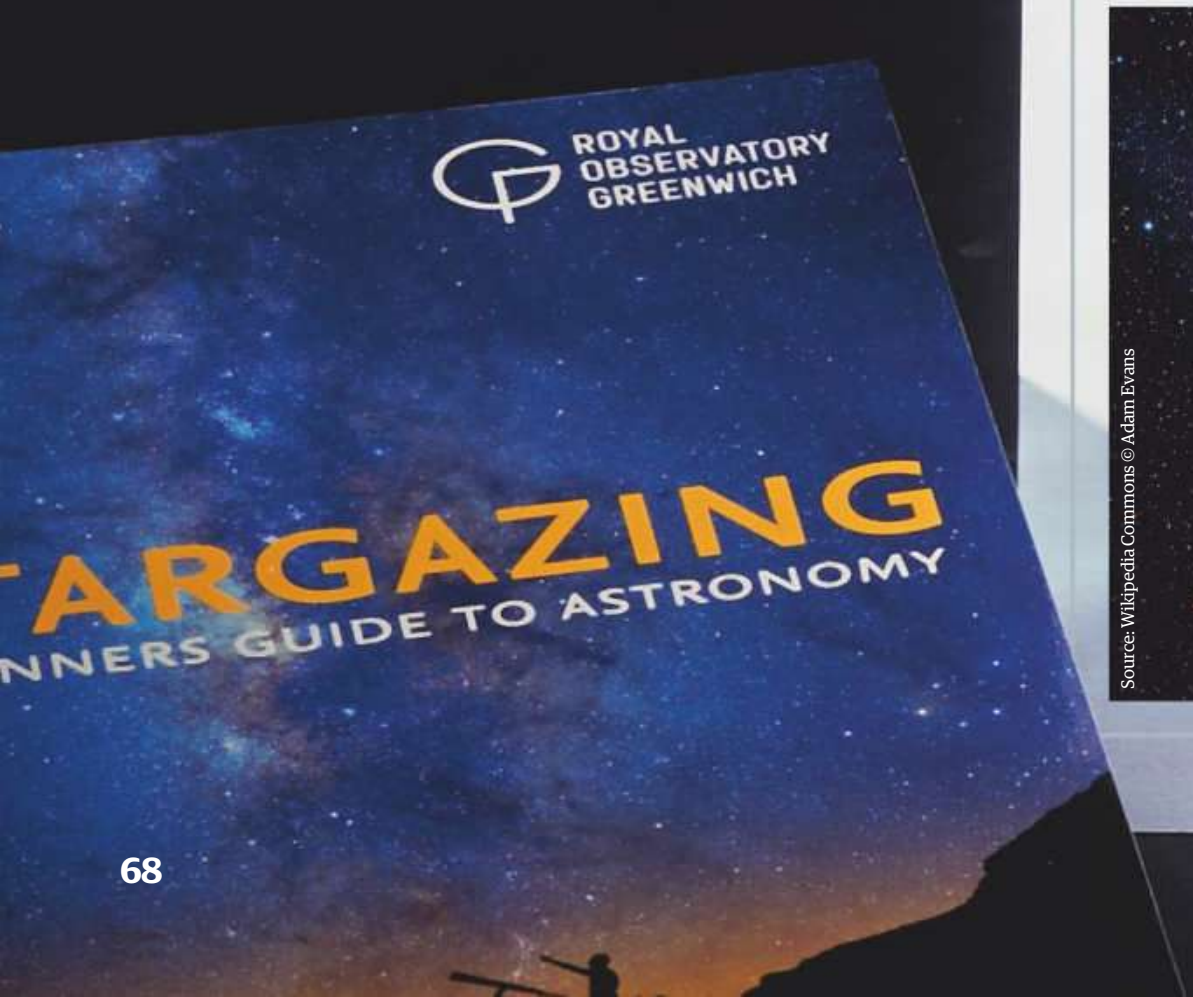
22 SEP
September equinox, marking the first day of autumn for the Northern Hemisphere

25 SEP
The Moon, Jupiter and Saturn pass within at least 1°35' of each other in Sagittarius


Source: Wikipedia Commons © Adam Evans

1 OCT
Dwarf galaxy Messier 110 is well placed for observation, shining at +8.9 in Andromeda

1 OCT
The Andromeda Galaxy (Messier 31) is well placed for observation, shining brightly at +3.4



Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

14 SEP
The Moon and Venus make a close approach, passing within 4°21' of each other in Cancer

17 SEP
Comet 88P/Howell will shine at its brightest at magnitude +8.6

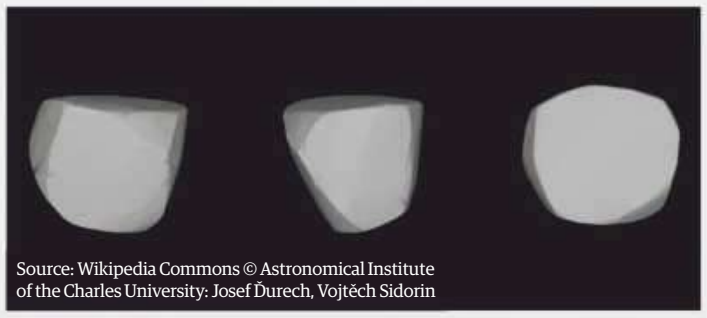
19 SEP
Conjunction between Mars and Eris, passing within 8°09' of each other in Pisces

27 SEP
The Daytime Sextantids reach their peak of five meteors per hour

30 SEP
Asteroid 68 Leto will be well placed for observation, shining brightly at +9.6 in Cetus

1 OCT
Mercury is at its greatest elongation east, glimmering at magnitude 0.0

1 OCT
Dwarf galaxy Messier 32 is well placed for observation, shining at +8.1 in Andromeda


Source: Wikipedia Commons © Astronomical Institute of the Charles University: Josef Ďurech, Vojtěch Sidorin

3 OCT
The Moon and Mars make a close approach, passing within 0°39' of each other in Pisces

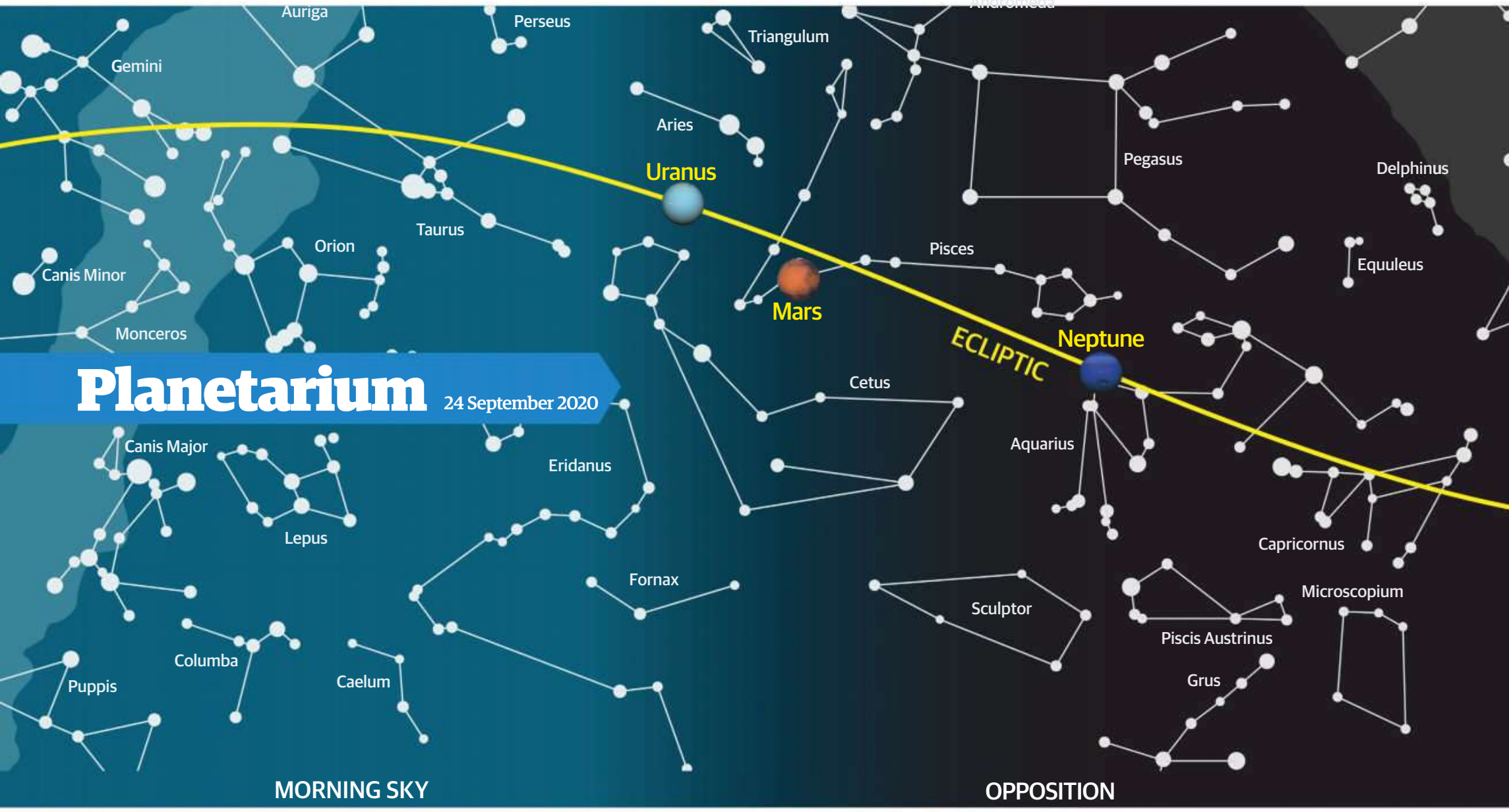
6 OCT
Mercury reaches half phase (dichotomy) in the evening sky, shining at magnitude +0.1

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

STARGAZER

Planetarium

24 September 2020



Moon calendar

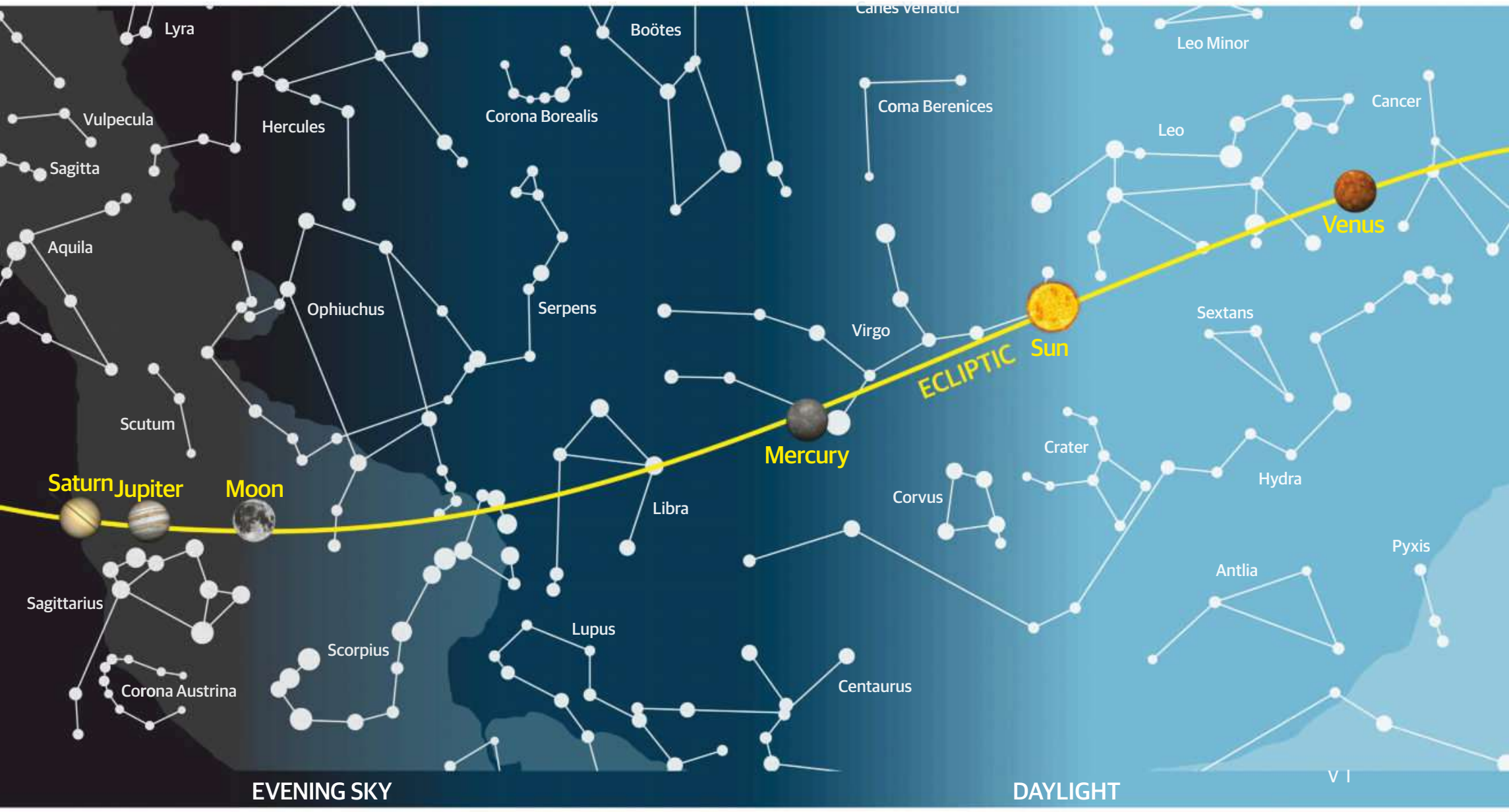
* The Moon does not pass the meridian on 30 September

10 SEP TQ 51.7% 15:05 23:05	**11 SEP** 41.4% 16:07 23:51	**12 SEP** 31.2% 17:03 --:--	**13 SEP** 21.5% 00:49 17:49	**14 SEP** 12.9% 01:59 18:26	**15 SEP** 6.0% 03:18 18:55	**16 SEP** 1.6% 04:43 19:20
17 SEP NM 0.2% 06:10 19:41	**18 SEP** 2.0% 07:38 20:01	**19 SEP** 6.8% 09:05 20:22	**20 SEP** 14.4% 10:32 20:44	**21 SEP** 24.0% 11:59 21:11	**22 SEP** 34.9% 14:15 23:11	**23 SEP** 46.3% 14:38 22:26
24 SEP FQ 57.6% 15:43 23:19	**25 SEP** 68.1% 16:35 --:--	**26 SEP** 77.5%* 00:21 17:15	**27 SEP** 85.5% 01:29 17:45	**28 SEP** 91.9% 02:40 18:09	**29 SEP** 96.4% 03:51 18:28	**30 SEP** --:--%* 05:01 18:45*
1 OCT FM 99.1% 06:10 19:00	**2 OCT** 99.8% 07:17 19:14	**3 OCT** 98.7% 08:24 19:30	**4 OCT** 95.7% 09:31 19:46	**5 OCT** TQ 91.0% 10:39 20:06	**6 OCT** 84.7% 11:48 20:30	**7 OCT** 77.0% 12:55 21:01
8 OCT 68.1% 13:59 21:42						

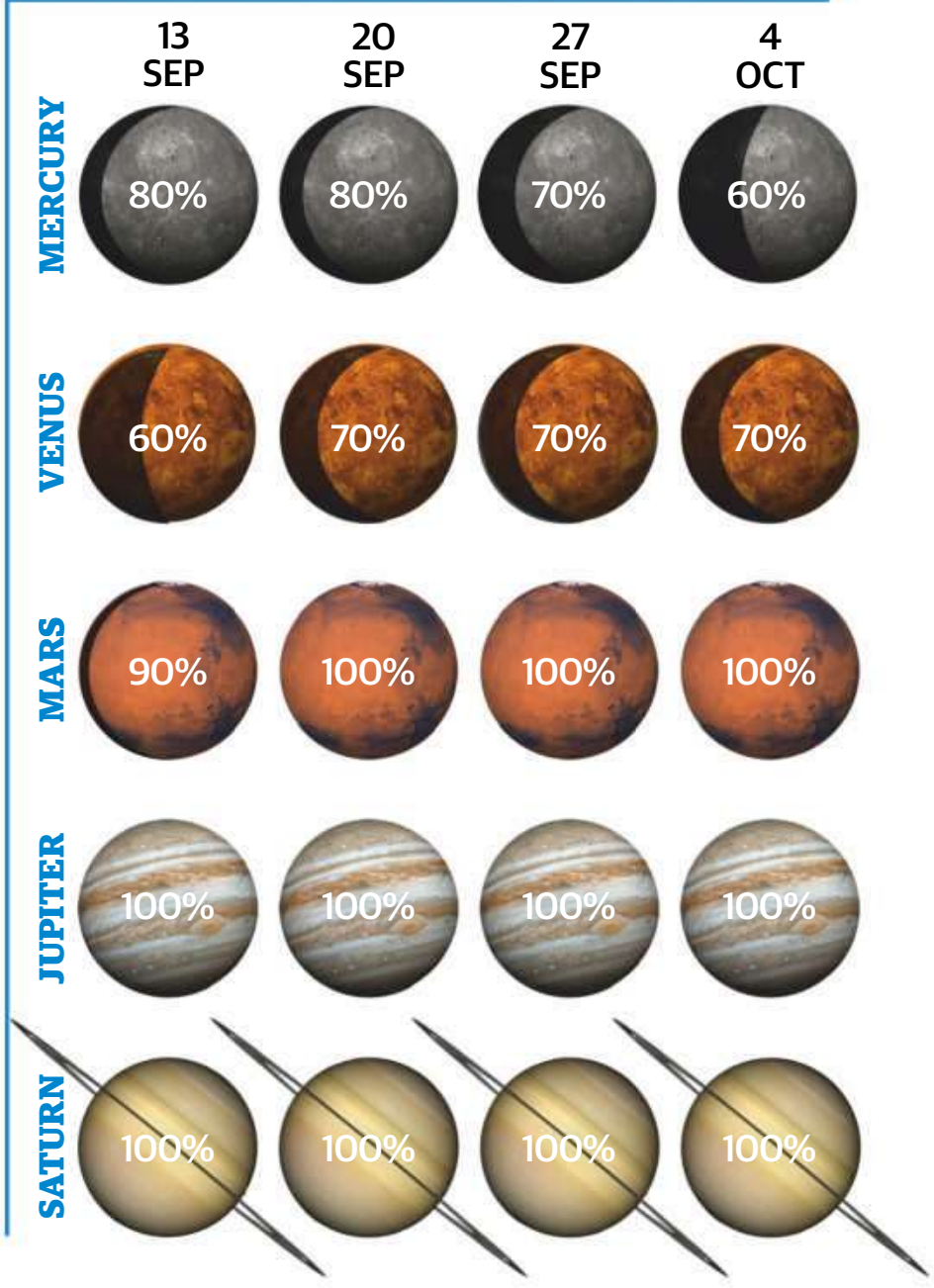
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

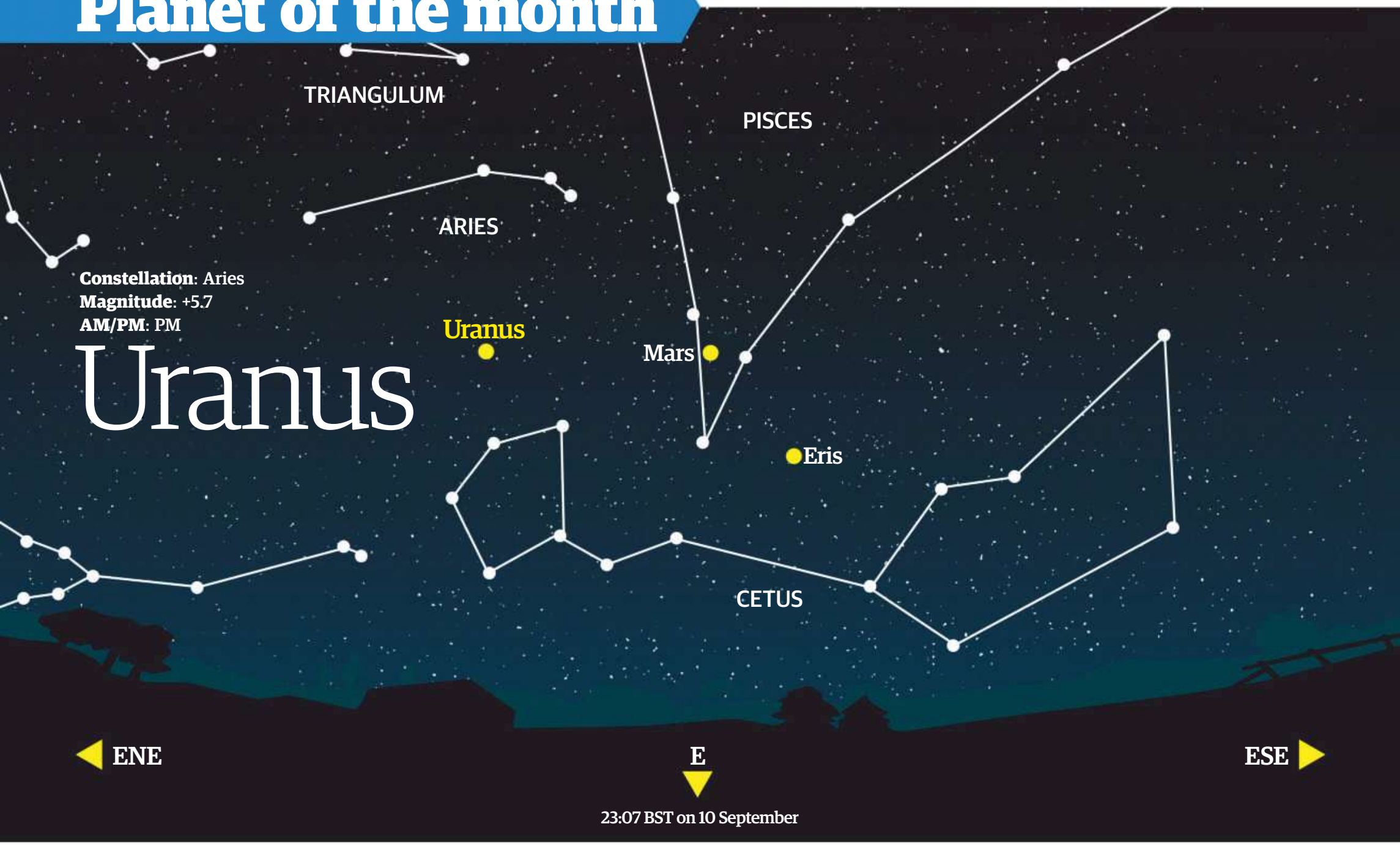
All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	10 SEP	12h 22m 52s	-02° 38' 38"	Virgo	-0.2	08:14	19:54
	17 SEP	12h 59m 20s	-07° 29' 52"	Virgo	-0.1	08:47	19:38
	24 SEP	13h 32m 39s	-11° 48' 19"	Virgo	0.0	09:16	19:21
	1 OCT	14h 01m 49s	-15° 20' 59"	Virgo	0.0	09:37	19:03
	7 OCT	14h 21m 12s	-17° 30' 41"	Virgo	+0.1	09:45	18:46
VENUS	10 SEP	08h 23m 05s	+18° 07' 29"	Cancer	-4.2	02:23	17:46
	17 SEP	08h 55m 13s	+16° 39' 04"	Cancer	-4.1	02:37	17:42
	24 SEP	09h 27m 20s	+14° 47' 15"	Leo	-4.1	02:52	17:35
	1 OCT	09h 59m 19s	+12° 34' 00"	Leo	-4.1	03:09	17:27
	7 OCT	10h 26m 35s	+10° 24' 36"	Leo	-4.1	03:25	17:19
MARS	10 SEP	01h 49m 34s	+06° 45' 08"	Pisces	-2.0	20:50	10:10
	17 SEP	01h 48m 03s	+06° 42' 21"	Pisces	-2.2	20:22	09:41
	24 SEP	01h 43m 48s	+06° 29' 08"	Pisces	-2.4	19:51	09:08
	1 OCT	01h 37m 13s	+06° 08' 02"	Pisces	-2.5	19:19	08:32
	7 OCT	01h 30m 13s	+05° 46' 13"	Pisces	-2.6	18:50	08:00
JUPITER	10 SEP	19h 14m 31s	-22° 45' 10"	Sagittarius	-2.5	16:57	00:56
	17 SEP	19h 14m 34s	-22° 45' 24"	Sagittarius	-2.5	16:30	00:28
	24 SEP	19h 15m 18s	-22° 44' 24"	Sagittarius	-2.4	16:03	23:58
	1 OCT	19h 16m 42s	-22° 42' 08"	Sagittarius	-2.4	15:36	23:32
	7 OCT	19h 18m 24s	-22° 39' 11"	Sagittarius	-2.3	15:14	23:10
SATURN	10 SEP	19h 49m 28s	-21° 21' 19"	Sagittarius	+0.4	17:23	01:40
	17 SEP	19h 48m 43s	-21° 23' 39"	Sagittarius	+0.4	16:55	01:11
	24 SEP	19h 48m 19s	-21° 25' 07"	Sagittarius	+0.4	16:27	00:43
	1 OCT	19h 48m 14s	-21° 25' 40"	Sagittarius	+0.5	15:59	00:16
	7 OCT	19h 48m 26s	-21° 25' 27"	Sagittarius	+0.5	15:36	23:48

This month's planets

Dusk to dawn belongs to the ice giants this month, as Jupiter offers a spectacular view before dipping out of sight

Planet of the month



Constellation: Aries
Magnitude: +5.7
AM/PM: PM

Uranus

Uranus marks a turning point in our exploration of the Solar System, discovered by William Herschel in 1781 from the city of Bath. Uranus is tipped on its side by 98 degrees – it appears to roll around the Sun, and currently its north pole is facing us at an angle of 50 degrees. Scientists are not sure why Uranus is on its side, but suspect a giant impact long ago may have knocked it over.

Uranus is an ice giant, which is a mysterious kind of gaseous world that also contains lots of ices – water, methane, nitrogen and so on – and our lack of knowledge about this kind of world is not helped by the fact that only one spacecraft has ever visited Uranus to explore it – NASA's Voyager 2 mission back in 1986.

Throughout autumn Uranus can be found slowly wandering through the southern part of the constellation of Aries, the Ram. It comes to opposition on the night of 31 October and reaches a healthy 54 degrees above the horizon in the sky, which is the highest it has been seen from the UK in over five decades. Uranus shines at magnitude +5.7, which means that technically it can be seen without binoculars or a telescope, but you would need a very dark sky and to know exactly where to look, so almost everyone will need a telescope to see it.

Uranus will appear as a fuzzy, turquoise disc when seen through a 100mm-aperture telescope. It is unlikely that you will be able to see any details on its globe – it takes a very large aperture, in excess of 300mm, or the talents of the best astrophotographers – to tease out any vague details, and indeed Uranus notoriously appeared bland when Voyager 2 visited it. The same goes for its five main moons, which shine at around 14th magnitude, but the accomplishment comes from just seeing the planet that lies 2.84 billion kilometres (1.76 billion miles) away from us.

Look for Uranus from about 23:00 BST onwards this month, when it has climbed up to about 15 degrees in the sky and the sky has become sufficiently dark. Uranus should then be visible, climbing higher and higher in the sky until dawn breaks the following morning.

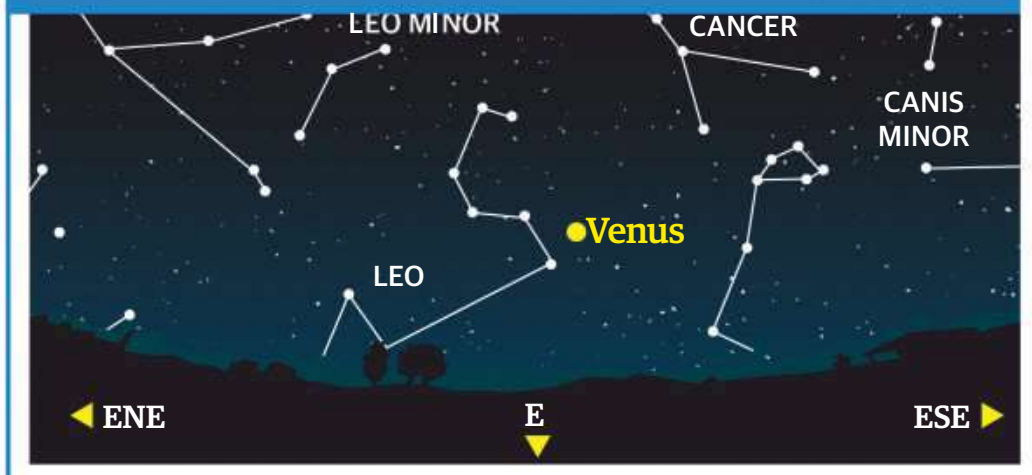
This month's planets

Mercury 19:07 BST on 22 September

Constellation: Virgo
Magnitude: -0.2
AM/PM: PM

Mercury, the innermost planet, is better seen from the Southern Hemisphere during September and early October than the Northern Hemisphere. It reaches what astronomers call its 'greatest eastern elongation' from the Sun – its maximum distance to the east in the sky from the Sun – on 1 October.

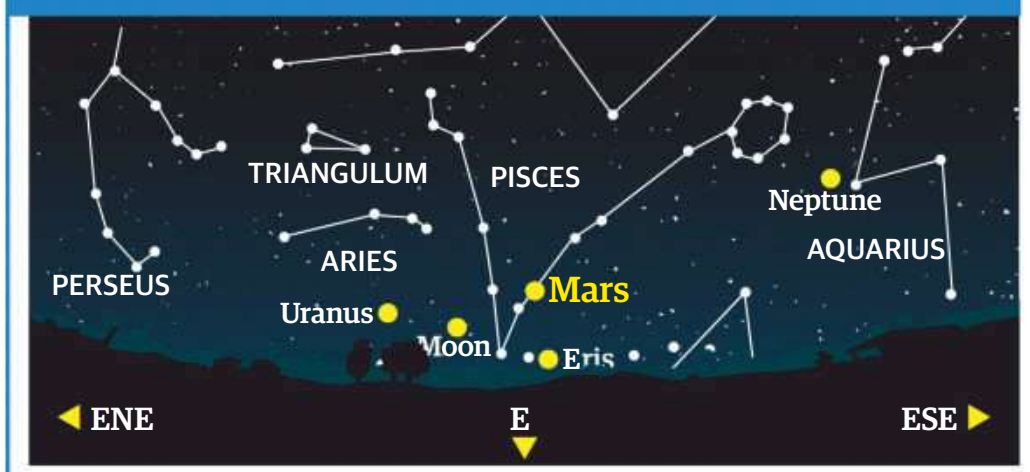
Venus 04:15 BST on 30 September



Constellation: Leo
Magnitude: -4.2
AM/PM: AM

Venus can be seen shining brightly before dawn. To identify it, just look to the east before the Sun comes up – it will be the brightest 'star' in the sky. Telescope or binocular users can look forward to Venus passing close to both the Moon and Messier 44, the Beehive Cluster, in Cancer in the early hours of 14 September.

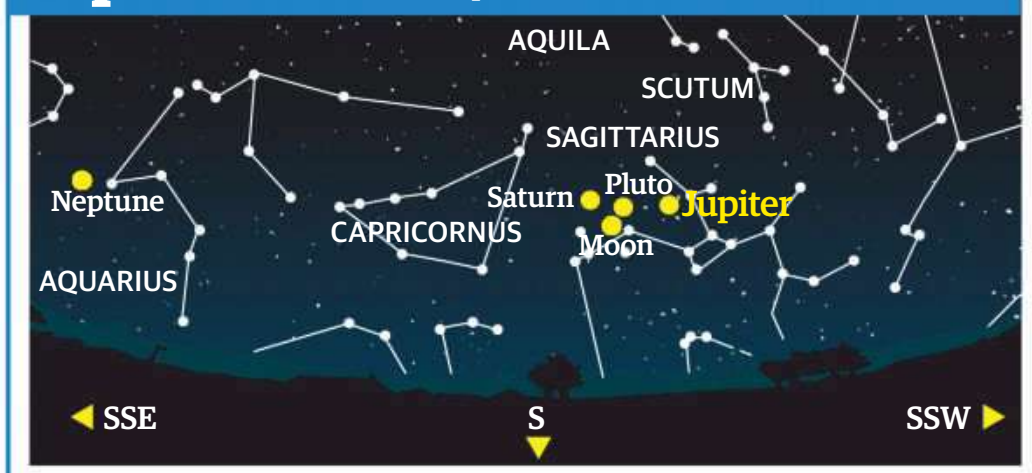
Mars 20:08 BST on 03 October



Constellation: Pisces
Magnitude: -2.1
AM/PM: PM

Mars is nearly at its best for this year – it will be at opposition on 13 October. Throughout September it brightens from magnitude -1.8 to -2.5 as it also begins to move retrograde – as if it's moving backwards. Look for Mars rising in the east at about 21:30, and the Red Planet is visible all night.

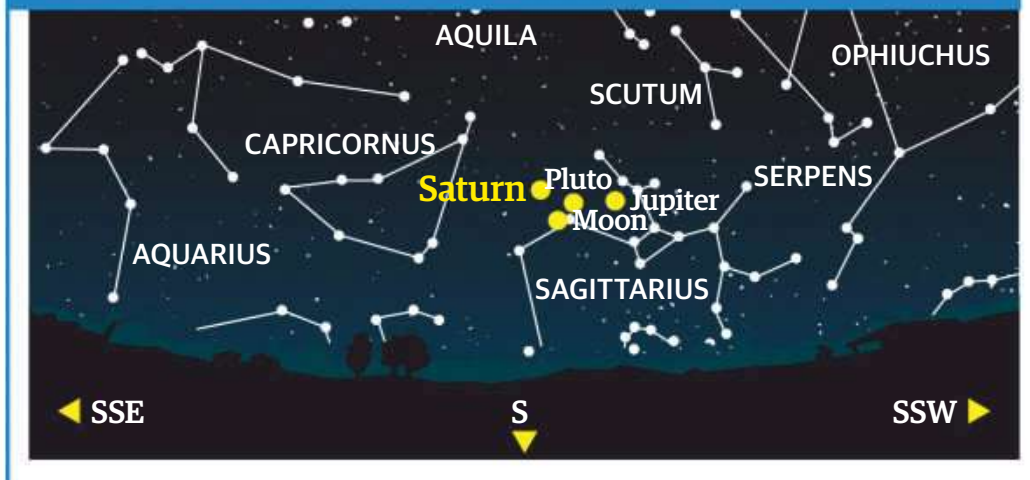
Jupiter 20:00 BST on 25 September



Constellation: Sagittarius
Magnitude: -2.5
AM/PM: PM

Its low height in the sky still can't obscure Jupiter's brilliance as a shining blue-white orb hanging over the southern horizon. A small telescope, or perhaps even binoculars, will show Jupiter's four Galilean moons – namely Io, Europa, Ganymede and Callisto – orbiting and transiting the planet.

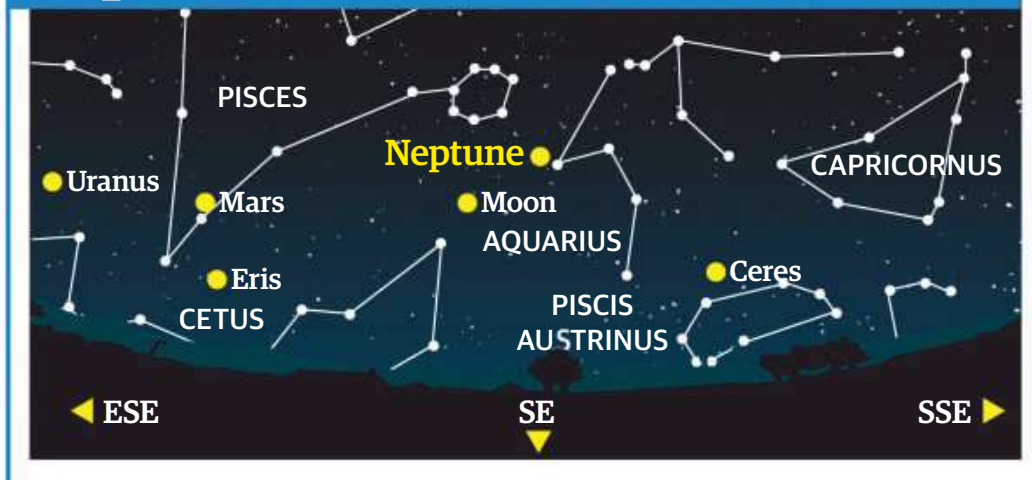
Saturn 20:00 BST on 25 September



Constellation: Sagittarius
Magnitude: +0.4
AM/PM: PM

The ringed planet has been following Jupiter around in the sky all summer, a dynamic duo in the southern sky. Like Jupiter, Saturn's low elevation of just 16 degrees hampers observation, particularly if you have rooftops and trees in the way, but if you have a clear horizon then Saturn is obvious.

Neptune 21:00 BST on 30 September



Constellation: Aquarius
Magnitude: +7.8
AM/PM: PM

The Solar System's other ice giant, Neptune, comes to opposition on 11 September, when it will be at its brightest for the year. Unfortunately that's not saying much – at a distance of 4.3 billion kilometres (2.6 billion miles), Neptune is so far away that it appears rather faint even when at its best.

Top tip!

The Straight Wall is easiest to see when it is near the terminator, the line between lunar night and day.

Moon tour

Rupes Recta (Straight Wall)

How to find the most dramatic cliff on the face of the Moon

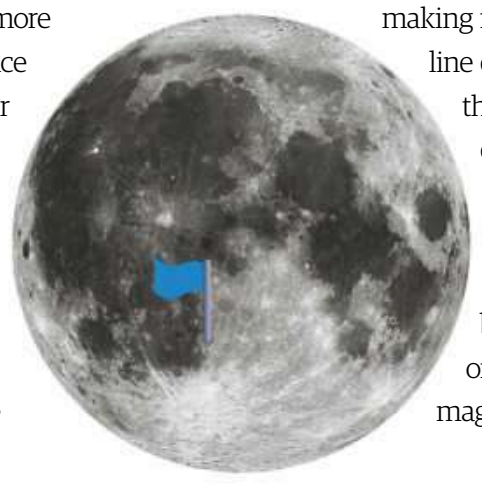
If you have a small telescope, or a powerful pair of binoculars, and look to the lower left of the great triple-crater chain of Ptolemaeus, Alphonsus and Arzachel you will see – depending on the time of the month – either a short, dark line or a short, bright line. Moon atlases and phone apps identify it as 'Rupes Recta', and to be honest it doesn't look like much at first glance, nothing more than a dark pencil line or a white chalk scratch drawn on the Moon's round, grey face. But Rupes Recta has another name, and it is one of the most famous and beloved features on the whole of the Moon. It's known as the 'Straight Wall'. It's not actually a wall. It is an enormous scarp, a region where part of the Moon's surface dropped dramatically away, leaving a steep cliff behind.

That cliff is very narrow, nowhere near as wide as the terraced rims of those three giant craters blasted out of the Moon to its north. It's not that tall either: with a maximum height of around 450 metres (1,476 feet), it's roughly as tall as the London Eye, or two nuclear submarines balanced end to end. And although the Straight Wall gives the impression of being a towering cliff face, it's not. Pre-Apollo space artists depicted the Straight Wall as vertical – a frozen tsunami wave of grey lunar stone – but if you stood at its base its slope would rise at an angle of only 30 degrees or so.

So Rupes Recta turns out to be not very wide, or very high. The Straight Wall's remaining claim to fame is that it is very long. Stretching more than 110 kilometres (68 miles) across the lunar surface, it would reach from London to the Isle of Wight if placed on Earth – or from Carlisle to Edinburgh if you prefer a more northerly comparison. That's so long that it would have taken Apollo astronauts more than eight hours to trundle and bounce from one end to the other in the lunar rover which was used on the Moon in the later missions.

The Straight Wall will first become visible on 25 September, when the Moon will be just past its first quarter phase. On that evening, with sunlight illuminating it from the east, its cliff face will be in shadow, so it will look like a very obvious short, dark line to the lower left of Arzachel, very close to a small, deep pit of a crater called 'Birt'. As sunlight creeps across the Moon's face and the cliff's shadow retreats, the Straight Wall will slowly turn into a bright line which seems to sink down into the Moon, becoming harder and harder to see until it is barely visible at all at full Moon.

The best time to see the Straight Wall will be after midnight on 10 October, when the Moon has just passed last quarter. Now illuminated from the west, Rupes Recta's cliff face will be bathed in full sunshine, making it appear as a strikingly bright line etched into the darker surface of the Moon, looking as if it has been dug out of the ancient, frozen lava flows of Mare Nubium by the tip of a knife's blade. At this time it will be visible in a good pair of binoculars, but telescopes will offer the best views, the higher the magnification the better.



© NASA

Naked eye & binocular targets

Glittering stars and spectacular spiral galaxies are easy finds in the night sky

5 The Pinwheel Galaxy (Messier 101)

One of the most observed galaxies in the sky, Messier 101 is known as the 'Pinwheel' because of its almost-perfect spiral shape. It is thought to be twice the size of our own Milky Way, and is more than 27 million light years away. It is visible in binoculars as a faint patch of light.

2 Polaris (the Pole Star)

Second-magnitude Polaris is the 48th-brightest star in the sky. It is directly above Earth's rotational axis, which means it is the only star that stands still in the sky. Its nickname is 'the Pole Star', but it won't be that forever – by the year 14,500, Vega will become our new north star.

Corona Borealis

Draco

Boötes

Ursa Minor

2

3

5

1

4

4 The Whirlpool Galaxy (Messier 51)

This beautiful spiral galaxy, the same size as our own Milky Way, contains more than 160 billion suns and lies more than 23 million light years from Earth. It looks like a very small, round patch in binoculars close to the star marking the tip of the Great Bear's tail.

Ursa Major

Coma Berenices

Canes Venatici

3 Arcturus (Alpha Boötis)

The fourth-brightest star in the entire sky, magnitude -0.05 Arcturus is a giant star almost 30-times wider than our Sun. Only 37 light years away – close in cosmic terms – its nickname is 'the Bear Watcher' due to its proximity to Ursa Major (the Great Bear).

1 Mizar and Alcor

One of the most famous double stars in the sky, Mizar and its close companion Alcor were once used as a test of good eyesight. Today we know they are actually six stars orbiting around each other, more than 78 light years from Earth.

California Nebula
(NGC 1499)

Deep sky challenge

Treasures of Perseus and Cassiopeia

A ghostly nebula and a rose-shaped star cluster are among your observing challenges this month

Source: Wikipedia Commons ©Remitdone

We've got some real observing challenges for our readers this month, with faint gems hidden among the bright, familiar stars of the much loved constellations of Perseus and Cassiopeia. However, with the sky staying bright until the very small hours at this time of year you'll need to stay up late or get up early to see them.

NGC 7789 is a loose cluster popularly known as 'Caroline's Rose'. Discovered by Caroline Herschel in 1783, its many loops of stars and the dark gaps between them give it – some observers claim – a strong resemblance to a white rose. See what you think when you have it in the middle of your telescope's eyepiece.

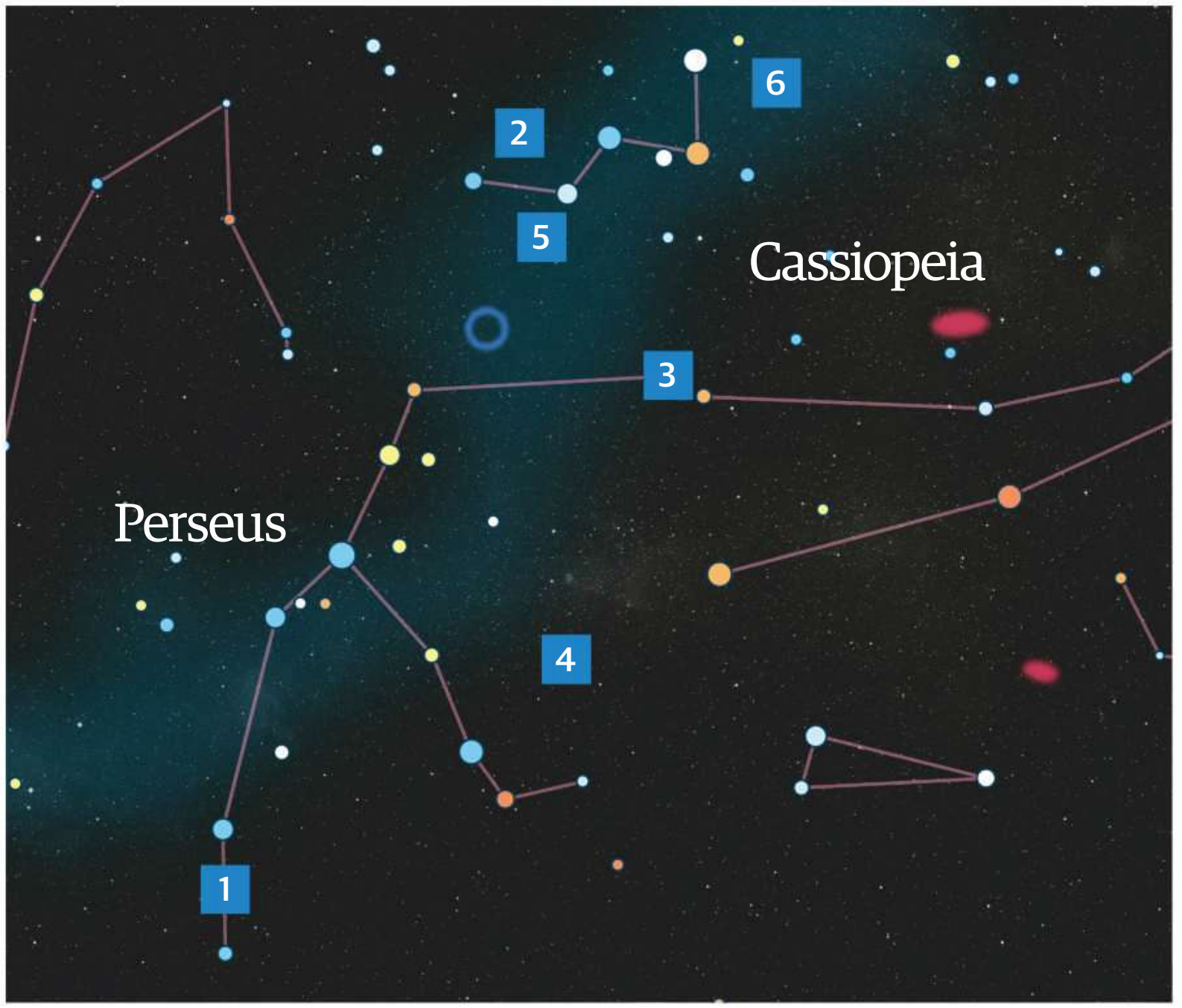
Messier 76 is a planetary nebula nicknamed the 'Little Dumbbell Nebula' and is infamous among deep-sky observers as one of the hardest to see of Messier's catalogue of 110 objects. Definitely one for the owners of large-aperture 'light buckets' to try and hunt down.

Owners of small telescopes aren't left out, however. The pretty little magnitude +5.6 cluster Messier 34 is worth looking at through any telescope at any time.

Caroline's Rose
(NGC 7789)

Source: Wikipedia Commons ©Hewholooks

Deep sky challenge



Source: Wikipedia Commons ©Vanderbei

1 The California Nebula (NGC 1499)

NGC 1499 is quite large, but its very low surface brightness means it is hard to see in small telescopes. It is only seen properly through light-gulping medium- or large-aperture instruments.

2 NGC 559

This ninth-magnitude loose open cluster in Cassiopeia contains several dozen stars and is best seen in medium-aperture or larger telescopes. It is 3,700 light years away and approximately 4' across.

3 Little Dumbbell Nebula (Messier 76)

Magnitude +10.1 M76 is one of the most difficult to find of all of Messier's objects; only large instruments will show it clearly. Despite its nickname it looks more like a misty elongated patch than a twin-lobed dumbbell.

4 Messier 34

Just north of Algol, M34 is a very loose open cluster of 100 or so stars covering the same size area as the full Moon. Small telescopes give the best view of the trio of arms coming from its centre.

5 Messier 103

This magnitude +7.4 open cluster is one of the sky's 'hidden gems'. Small- and medium-aperture telescopes give lovely views of the 'miniature Orion's Belt' across its centre, an orange star with an icy blue star on either side.

6 Caroline's Rose (NGC 7789)

The stars in magnitude +6.7 NGC 7789 are so densely packed that some think it looks more like a globular cluster than a loose cluster. Either way, medium- and large-aperture telescopes are needed to see the stellar petals' subtle outlines.

"MESSIER 34 IS WORTH LOOKING AT THROUGH ANY TELESCOPE AT ANY TIME"

STARGAZER

The Northern Hemisphere

The skies have darkened as we head into autumn, with some favourites returning

Cassiopeia (the Queen) and Cepheus (the King) lie in the dusty path of the Milky Way, offering not just a rich star field, but impressive deep-sky objects too. The Owl Cluster (NGC 457) is particularly easy to pick out with decent binoculars, its 75 to 100 bright stars forming the shape of an owl with spread wings, while the bright double star Phi Cassiopeiae forms the celestial bird's eyes. Double star Alpha Cassiopeiae is easy to split, resolving a bright, yellow primary and faint, blue secondary and providing delightful views. Use the constellations of Pegasus, Aquarius and Pisces and you'll be able to locate Cetus (the Sea Monster), which contains the remarkable variable star Mira as well as a wide selection of galaxies.

Using the sky chart

This chart is for use at 22:00 (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

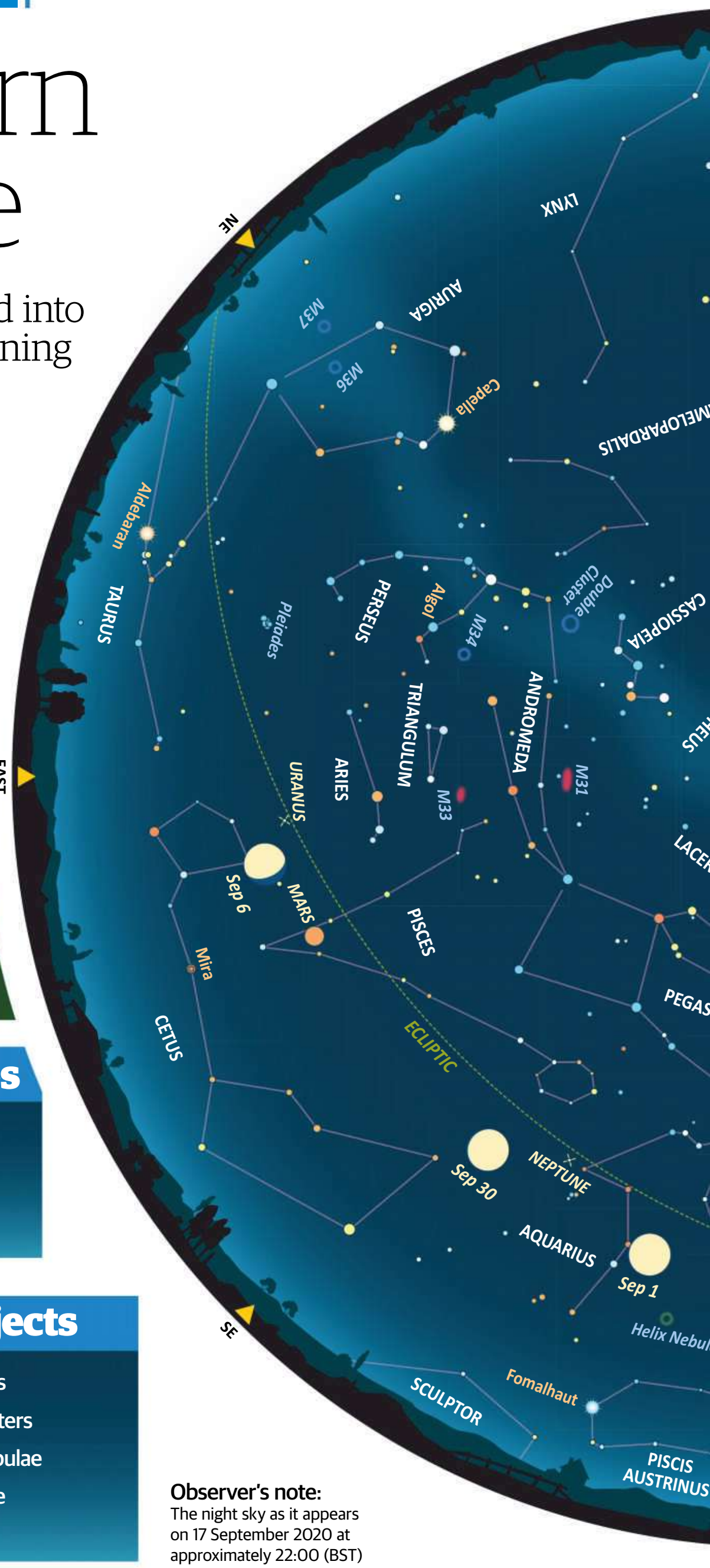
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

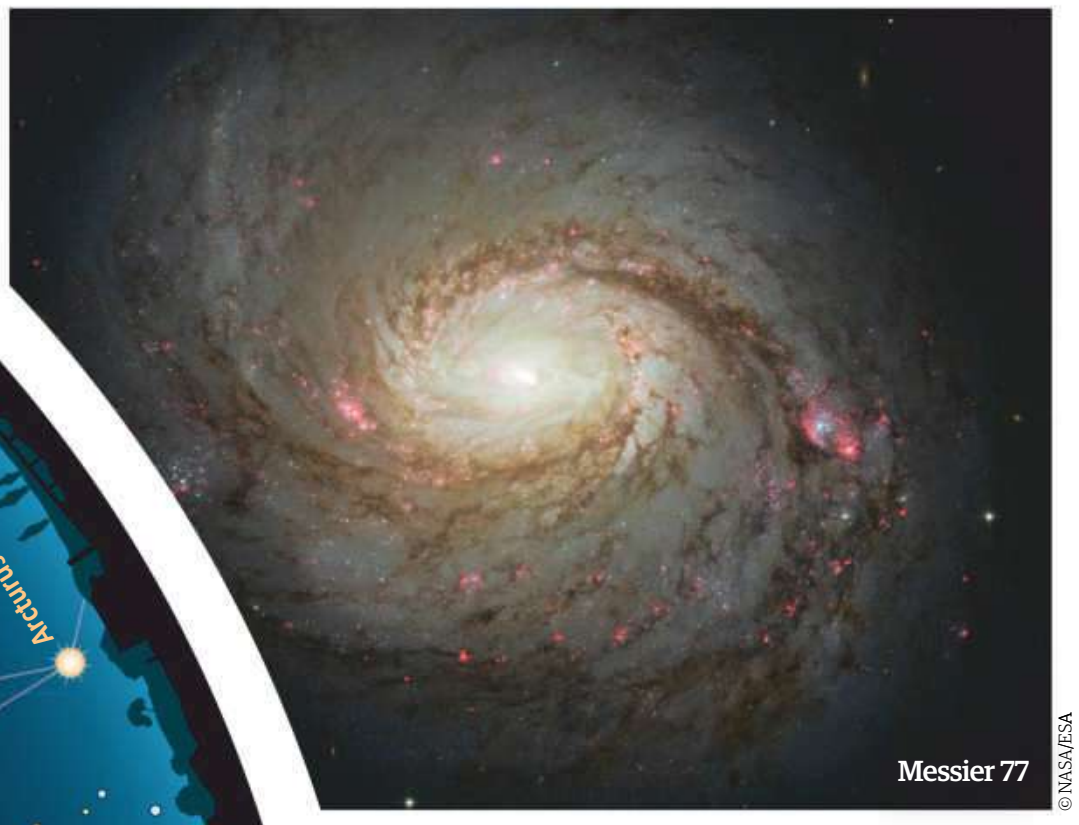
Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 17 September 2020 at approximately 22:00 (BST)

The Northern Hemisphere



Messier 77

© NASA/ESA

Iris Nebula (NGC 7023)

Source: Wikipedia Commons © KeithSteffens

Pacman Nebula (NGC 281)

Source: Wikipedia Commons © Chuck Ayoub

20

Celestron NexStar 127 SLT

A small telescope that packs a punch, this Maksutov-Cassegrain is an ideal companion for observations of the Solar System

Telescope advice

Cost: £579.00 (approx. $754)
From: David Hinds Ltd
Type: Maksutov-Cassegrain
Aperture: 5"
Focal length: 59"

Best for...

- Beginners
- Medium budgets
- Planetary viewing
- Bright deep-sky objects
- Lunar viewing
- Basic astrophotography

If you're looking for an affordable entry-level telescope for planetary viewing that will take a few years to outgrow, then the NexStar 127 SLT could be the instrument for you. With a price tag of £579.00, we also think that this Maksutov-Cassegrain is a worthy contender for those wishing to upgrade on a more basic entry-level scope.

Unboxing the 127 SLT, the telescope's high quality was immediately noticeable, and setting it up was nothing short of a breeze. If this is your first time using a computerised scope and you're concerned about putting it together, there's no need to worry – the procedure in getting the GoTo facility up and running is fairly straightforward, meaning that the 127 SLT is fully functional in a matter of minutes. Celestron provides a step-by-step guide along with software to help you with alignment. We do recommend that you have a very good idea of how the SkyAlign software works before heading outside for the evening, however, as reading instructions in the dark may prove to be difficult and will become quite frustrating if you haven't digested the steps required for an easy set up. The mount includes a spirit level, and it's important to make use of this to ensure that the GoTo system is able to achieve optimum performance. Once completely set up the 127 SLT is extremely portable, making it ideal for astronomers who like to switch between observing in their garden and travelling to darker sites.

We chose three bright stars that were sufficiently separated for alignment, with the telescope responding very well to our choices, and it wasn't long before we began touring the night sky. The GoTo system responded very well during our review, and will certainly take the pain out of locating objects for those who struggle to find their way around the heavens.

Unfortunately, however, this Maksutov-Cassegrain does have a few downsides. The 127 SLT is quite top-heavy, and while it wasn't on the brink of falling over, we do recommend investing in a tripod that's able to hold the mount and tube much more steadily. Additionally, the tripod vibrates while the GoTo's motors are in motion, and even with the slightest touch of the focus knob.

As a result we needed to stop and start focusing for a steady view since the target bounced around the field of view if we tried to look through the eyepiece and bring the object into focus simultaneously. Another problem that we found is that the telescope is quite demanding of the eight AA batteries that it requires. It's a given that they won't last for very long in cold conditions, and the supplied batteries were drained in just a couple of hours of observation. We recommend investing in good batteries, being mindful of a sufficient voltage. We also think it's wise to purchase a 12V DC power supply for powering the GoTo, something the telescope isn't supplied with.

> "IF THIS IS YOUR FIRST COMPUTERISED SCOPE AND YOU'RE CONCERNED ABOUT PUTTING IT TOGETHER, THERE'S NO NEED TO WORRY"

For our review we took advantage of a waning gibbous Moon using the supplied 9mm and 25mm Plössl eyepieces, which provided magnifications of 167x and 60x. Observing the lunar surface was breathtaking with this telescope, with craters, rilles and lunar mare being highly resolved and extremely clear. We ran along the Moon's terminator, taking in exquisite views of the rugged surface where bright meets dark. The craters Catharina, Aristoteles and Cyrillus were particularly stunning, with shadows falling across them beautifully and truly making them pop. Heading over to brighter craters Tycho, Longomontanus and Clavius, the 127 SLT's optical system once again produced beautiful, clear and crisp results.

The telescope's database contains around 4,000 objects. Sadly, however, a good proportion of these are faint deep-sky objects that the 127 SLT's optical system just isn't capable of viewing due to its long focal length and small aperture. You will be able to make a smudge of light out when

Left: The fork arm will allow for some basic astrophotography

Celestron NexStar 5 SLT

Main: The telescope is made of sturdy stainless steel, but does shake when the GoTo motors are in operation – and even with the slightest touch of the focusing knob

Below: The 127 SLT's optical system makes it a very good telescope for touring the Solar System

observing galaxies, but this telescope is best used for Solar System objects and some brighter deep-sky targets. We were able to resolve Jupiter's cloud bands with ease given the steady seeing conditions, and cleanly separated several pairs of double stars. Views are clear across an excellent proportion of the field of view, and as expected with catadioptric telescopes, any colour fringing is nowhere to be seen.

Since the telescope makes use of an alt-azimuth single-arm mount, it's difficult to use it for advanced astrophotography. However, we were able to get fair images using a DSLR camera and short exposures – something that individuals who fit into the beginner to intermediate level of astronomy will no doubt be pleased with.

We're impressed with the NexStar 127 SLT's performance along with the versatility in accessorising it further. If your interests lie in planetary or lunar targets, then this telescope is an affordable instrument with stunning optics.

Robert Lawrence

Selected as the first African-American astronaut, but tragically died before he could reach space

In June 1967 Major Robert H. Lawrence Jr. was selected as the first African-American astronaut by any national space program. Unfortunately this is a story that doesn't have a happy ending. Tragedy struck, and Lawrence was never able to make his ascent into space.

Born in Chicago, Illinois, on 2 October 1935, Lawrence was a bright young man, receiving a bachelor's degree in chemistry from Bradley University, Peoria, Illinois, at the age of 20. He then moved swiftly into the United States Air Force (USAF) as an officer and pilot. While completing over 2,500 hours of flight – 2,000 of these in jets – as an officer of the USAF, he also gained a PhD in physical chemistry from Ohio State University, Columbus, Ohio, in 1965.

Between 1963 and 1969 – the latter of which saw humans first step foot on the Moon – the USAF and the National Reconnaissance Office were working on a partially classified project referred to as the Manned Orbiting Laboratory (MOL). This project planned to put small space stations into low polar orbits, which were going to be occupied by two people for 30 days at a time. The method of transportation between the ground and these space stations was going to be modified Gemini capsules.

The MOL project was intended to aid the military. It would essentially be used for espionage activities concerning the nation's Cold War adversaries, collecting high-resolution photographic imagery in the process. Lawrence was chosen as a member of the third group of aerospace research pilots in 1967, making him the first African-American chosen to become an astronaut and also making him the only MOL astronaut candidate with a doctorate.

Sadly Lawrence perished on 8 December 1967 as he participated in a test flight with another pilot in an F-104 Starfighter supersonic jet. They were testing landing manoeuvres that would later be used in the Space Shuttle program. When the MOL program was cancelled due to budgetary constraints in 1969, seven astronauts under the age of 35, which would have included Lawrence,

© US Air Force

Lawrence logged over 2,500 hours of flight, but was never able to fly in space

"Lawrence was chosen as a member of the third group of aerospace research pilots in 1967"

transferred to NASA and later flew on Space Shuttle missions. They have henceforth been known as NASA Astronaut Group 7.

Due to the semi-secret nature of the MOL program, Lawrence's achievements, involvement and untimely death went unknown to a large majority of the population for many years. It wasn't until the 1990s when these secrets were disclosed in order to "overcome bureaucratic barriers over the definition of an astronaut".

Many touching tributes to him have been made ever since, which is a testament to what an important American space pioneer he was. In September 1997, on the Space Shuttle Atlantis mission STS-86, the MOL mission patch was sent into space with the Space Shuttle crew. On the 30th anniversary of Lawrence's death his name was carved into the Astronauts Memorial Foundation Space Mirror at the Kennedy Space Center Visitor Complex in Florida. On the 50th anniversary of his death Lawrence was honoured by several of NASA's most prestigious figures at the time in a moving ceremony.

All About Space

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor-in-Chief **Gemma Lavender**
gemma.lavender@futurenet.com
Art Editor **Jonathan Wells**
Staff Writer **Lee Cavendish**
Production Editor **Nikole Robinson**
Research Editor **Baljeet Panesar**
Senior Art Editor **Duncan Crook**
Photography **Olly Curtis**

Contributors
Stuart Atkinson, Oscar Blanch-Bigas, David Crookes, Chelsea Gohd, Robin Hague, Elizabeth Howell, Erin Kara, Zoe Landsman, Samantha Mathewson, Kerry Paterson, Sean Solomon, Colin Stuart, Meenakshi Wadhwa, James Daniel Whitfield

Cover images
Tobias Roetsch; Getty

Photography
Alamy; ESA; ESO; NASA; Science Photo Library; Shutterstock; SpaceX; University of Arizona; Wikipedia Commons;
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Senior Advertising Manager **Amanda Burns**
amanda.burns@futurenet.com
0330 390 6036
Account Manager **Garry Brookes**
garry.brookes@futurenet.com
0330 390 6637

International Licensing
All About Space is available for licensing. Contact the Licensing team to discuss partnership opportunities.
Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com

Subscriptions
Enquiries **www.myfavouritemagazines.co.uk/en/contact**
UK orderline & enquiries **0344 848 2852**
Overseas order line & enquiries **+44 (0)344 848 2852**
Online orders & enquiries **www.myfavouritemagazines.co.uk**
CRM Director **Louise Dudfield**

Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Frances Twentyman**

Management
Chief Content Officer **Aaron Asadi**
Commercial Finance Director **Dan Jotcham**
Brand Director **Evan Kypreos**
Head of Art & Design **Greg Whitaker**

Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2050-0548

All contents © 2020 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

Widely Recycled

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill and paper hold full FSC and PEFC certification and accreditation.

FUTURE
Connectors. Creators. Experience Makers.

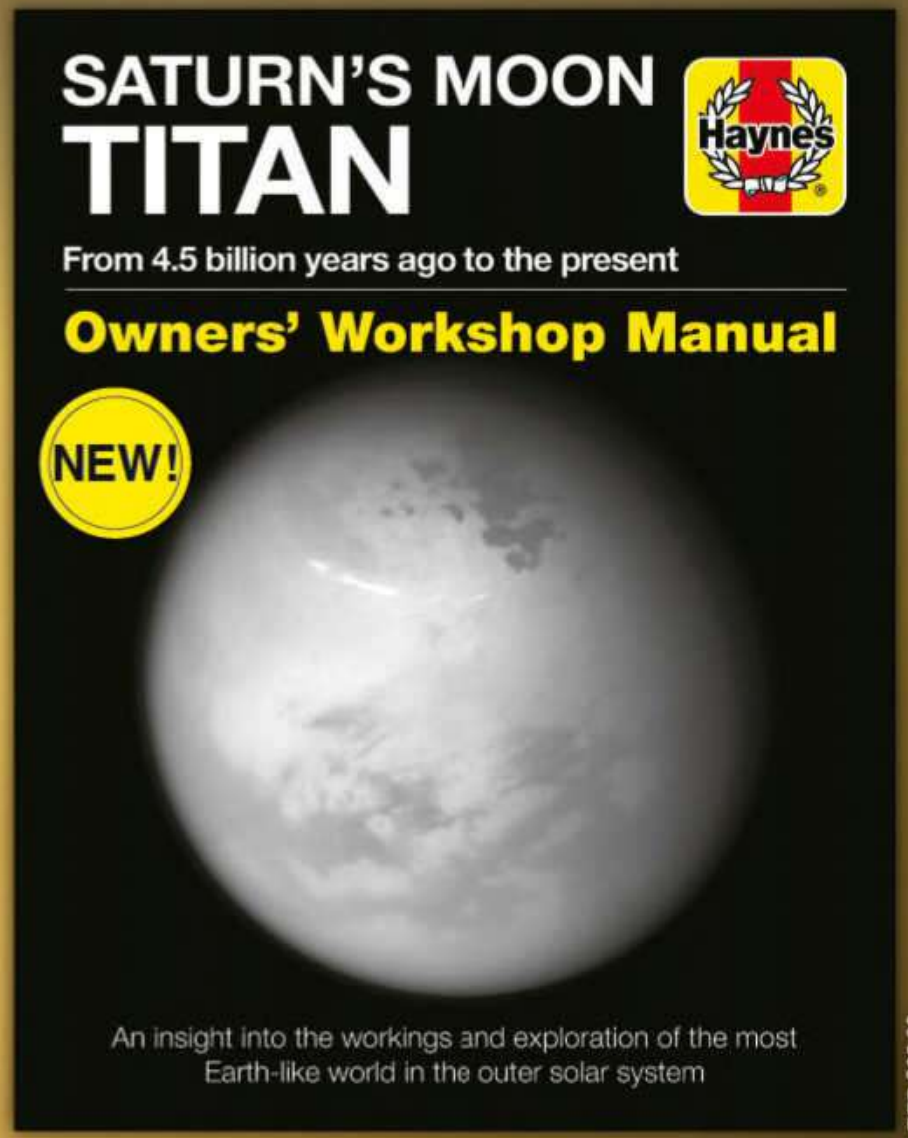
Future PLC is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

Chief Executive **Zillah Byng-Thorne**
Non-executive Chairman **Richard Huntingford**
Chief Financial Officer **Rachel Addison**
Tel +44 (0)1225 442 244

ipso Regulated

NEW FROM HAYNES

DISCOVER THE SECRETS OF THE SOLAR SYSTEM'S MOST FASCINATING MOON



MORE SPACE BOOKS FROM HAYNES

AVAILABLE AT **HAYNES.COM/SPACE** AND ALL GOOD BOOKSHOPS

Sky-Watcher®

Be amazed.

POPULAR BEGINNER & INTERMEDIATE NEWTONIAN REFLECTORS

Sky at Night MAGAZINE GROUP TEST WINNER

ASTROLUX
76mm f/9.2 REFLECTOR

SRP £89.99

SKYHAWK-1145P (EQ1)
114mm f/4.4 PARABOLIC REFLECTOR

Sky at Night MAGAZINE GROUP TEST WINNER

SRP £165

"The optics were so good.... the review instrument certainly delivered in every important respect"
BBC SKY AT NIGHT MAGAZINE

EXPLORER-130 (EQ2)
130mm f/6.92 REFLECTOR

SRP £195

"This telescope made observing the night sky enjoyable....great views coupled with ease of use"
BBC SKY AT NIGHT MAGAZINE

EXPLORER-150P (EQ3-2)
150mm f/5
PARABOLIC REFLECTOR

"Good for advanced observing... Saturn was a stunning sight"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE HIGHLY COMMENDED 87%

SRP £389

EXPLORER-150PL (EQ3-2)
150mm f/8 PARABOLIC REFLECTOR

SRP £389

EXPLORER-200P (EQ5)
200mm f/5 PARABOLIC REFLECTOR

"Passed all our tests with flying colours and was a delight to use both optically and mechanically"
BBC SKY AT NIGHT MAGAZINE

Sky at Night MAGAZINE GROUP TEST WINNER

SRP £585

SKYLINER-150P CLASSIC
153mm f/7.8 PARABOLIC DOBSONIAN

SRP £259

SRP £349

Sky at Night MAGAZINE HIGHLY COMMENDED 93%

"Turning to Saturn, the view really took our breath away....The Skyliner was a joy to use"
BBC SKY AT NIGHT MAGAZINE

SKYLINER-250P CLASSIC
254mm f/4.7
PARABOLIC
DOBSONIAN

SRP £519

SKYLINER-200P CLASSIC
203mm f/5.9 PARABOLIC DOBSONIAN

Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 111 August 2014

SRP £62.99

SRP £115

HERITAGE-100P
100mm f/4 PARABOLIC DOBSONIAN

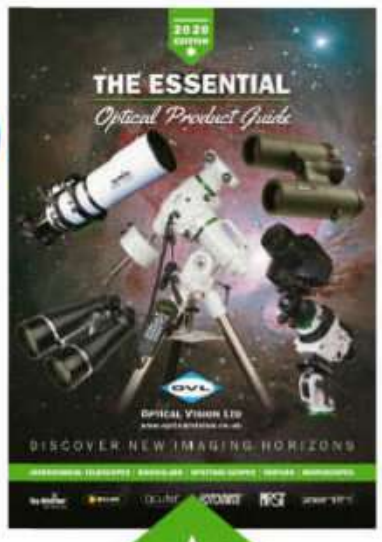
SRP £179

SRP £219

HERITAGE-76
76mm f/4 DOBSONIAN

HERITAGE-130P FLEXTUBE™
130mm f/5 PARABOLIC DOBSONIAN

HERITAGE-150P FLEXTUBE™
150mm f/5 PARABOLIC DOBSONIAN



Available from dealers throughout the UK

OPTICAL VISION LIMITED

Full product details at:
www.opticalvision.co.uk
info@opticalvision.co.uk

Email for 88 Page FREE Catalogue

9001

9000